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III. Pasteur and the Era of Bacteriology

THE story of bacteriology can best be told by recounting the labors of Pasteur, for while bacteria were known and theories of infection had been elaborated and vaccination practised before his time, it was he who definitely established the importance of bacteria in putrefaction, fermentation and disease, and gave to vaccination a scientific basis. The influence of these labors is compatible in medicine only to that of Virchow in his field and is as great as that exerted in general biology by Darwin's researches. The story of rapid sequence of Pasteur's brilliant discoveries in science, each of crucial importance and establishing a new principle have, I believe, no parallel in biology or, for that matter, any other science.

But before presenting Pasteur's labors it is necessary to outline the knowledge of bacteria and the theories of fermentation, infection and allied processes which were current at the beginning of his era.

Bacteria were first seen by Leeuwenhoek, a Dutch lens-maker in 1673. This was long before the day of the compound microscope, but Leeuwenhoek was able to make such excellent short focus single lenses that he could study red blood corpuscles and spermatozoa, detect minute globular particles in yeast, and, as we know from his drawings, even discover some of the larger microorganisms in the tartar of the teeth, in saliva and intestinal and other fluids. In 1838, about the time of the development of the compound microscope, Ehrenberg attempted a classification of bacteria based on sixteen species. Our exact knowledge, however, begins with Cohn's studies which extended from 1853 to 1875, and were the first to differentiate between the spherical forms

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which we call cocci, and the rod-like forms or bacilli. These early studies were almost exclusively botanical in nature and it was not until 1872 that Cohn could include definite disease-producing bacteria in his classification of the vegetable microorganisms.

Bacilli had been found, it is true, as early as 1850 in diseased animals, for example, the anthrax bacillus in animals dying of splenic fever. So also Schönlein in 1839 had discovered a vegetable parasite, a mycelial form, higher than the bacteria, in the disease of the skin known as favus; Malmsten in 1848 had found a somewhat similar form in barber's itch, and Bassi about 1832 had demonstrated that a disease of the silkworm was due to a minute cryptogamic plant. But the importance of these observations was not widely appreciated and no general relation was established between bacteria and disease in man.

Likewise, theories of infection which explained disease as due to invisible microorganisms had been propounded as early as 1762, as for example that of Plenciz, which, based on Leeuwenhoek's discoveries, ascribed to every disease its particular microorganism, explained the decomposition of animal and vegetable material as due to microorganisms, postulated the growth of bacteria in living tissues and suggested the possibility of the transmission of disease virus by the air. Such views, naturally, were without experimental basis and without even an objective knowledge of the microorganisms supposed to be etiologically concerned. In other words the propounder of this theory, as others after him, believed more than he could prove. By the middle of the century, however, observations on bacteria, largely as the result of the labors of botanists, were accumulating, and views about spontaneous generation, fermentation and infection were being discussed, but the fundamental experiments necessary to settle these problems were yet to be made, and, curiously enough, it was to a chemist, influenced by the methods of physics, who was to establish bacteriology as a biological science and to give to it the important place in medicine which it has occupied for the past thirty years.

Pasteur was this chemist, and his first great discovery was in crystallography, the explanation of the behavior of one of the tartaric acids to polarized light. This acid obtained from the lees of wine was, unlike other acids of the group, inactive to polarized light. This inactivity Pasteur demonstrated to be due to the fact that it was made up of two isomeric constituents. The crystals of one of these constituents bore hemihedral facets on the right side and rotated the plane of polarized light to the right, and those of the other bore similar facets on the left, and therefore, rotated to the left, but, as Pasteur found, when combined, these crystals did not rotate the plane of polarized light at all. This, the first of his discoveries, was in 1848, the year that Virchow was investigating typhus fever in Silesia. If it

is necessary to fix contemporary events more definitely I may introduce the fact that two years later Pasteur quotes Professor Biot as referring to his recent discoveries in crystallography as "a very California."

Now, this work of Pasteur on the tartaric acids not only opened a new field in crystallographic studies, but, of far greater importance, led to the discoverer's studies in fermentation. In the course of his work on the tartaric acids he found that if salts of the inactive acid were acted upon by a mould (*Penicilium glaucum*) the right-handed constituent was destroyed, but the left-handed remained unchanged; and from this he concluded that the change from an optically inactive to an optically active fluid, under such experimental conditions, could be due only to the presence of living matter causing the destruction of one component. This was the beginning of his studies of fermentation, and from this time his labors were those which eventually established the sciences of bacteriology and immunity.

The opportunity to study alcoholic fermentation came at Lille in 1854, at a time when Pasteur was professor of chemistry and dean to the faculty at that place. The manufacturers of the region had met with disappointment in the making of alcohol from beets, and one of them came to the new professor of chemistry for advice. Pasteur undertook daily visits to the factory and from these visits came the idea of studying the fermenting beet juice in the laboratory.

Fermentation, at the time Pasteur entered the field, was a subject involved in great obscurity, with only here and there a ray of light. Cagnaird-Latour, in 1836, had studied that ferment of beer called yeast, and had observed that it was composed of cells "susceptible of reproduction by a sort of budding, and probably acting on sugar through some effect of their vegetation." Schwann and Kützing a few years later reached the same conclusion, but were opposed at once by Liebig, who enunciated a theory of mechanical decomposition and denied in its entirety the theory that fermentation was a biological process. Also Berzelius, second only to Liebig as an authority, believed fermentation was due to contact, and elaborated a theory of catalytic force. With such weighty opposing opinion the observations of Cagnaird-Latour and Kützing were neglected and fermentation was regarded by all as a strange and obscure process and was so characterized by Claude Bernard in 1850.

Uninfluenced by these views, however, Pasteur, having recognized that living matter is essential for alcoholic fermentation, adhered strictly to the experimental method, and taking up the problem of lactic acid fermentation (the souring of milk), discovered that the same budding and multiplying of a cell went on in it as in alcoholic fermentation, but that the cell of lactic acid fermentation was different from that of alcoholic fermentation. He observed also that the form of the

cells changed according to the conditions of fermentation. Incidentally he demonstrated in alcoholic fermentation, the formation of glycerin and succinic acid in addition to the well-known products alcohol and carbonic acid. In short, the outcome was that Pasteur completely demonstrated that the fermentations which lead to the production of alcohol, vinegar, lactic acid and butyric acid are all due to the presence and growth of minute organisms, or, in his own words, "The chemical act of fermentation is essentially a correlative phenomenon of a vital act beginning and ending with it."

The demonstration of the part played by specific microorganisms in the different fermentations was, as may readily be seen, suggestive of the etiology of infectious diseases. It was in the midst of these labors that the Académie des Sciences conferred upon Pasteur the Prize for Experimental Physiology (for 1859), and it was Claude Bernard who drew up the report and dwelt upon the "physiological tendency in Pasteur's researches." Ten years before, Bernard had characterized the process of fermentation as "obscure."

The results of the investigation of fermentation led naturally to a debate among the academicians concerning spontaneous generation, and in this dispute Pasteur took a most important part. The older examples of spontaneous generation, as, for example, the development of mice from a mixture of soiled linen and cheese and of maggots from decomposing meat, had long been discarded, but the demonstration that fermentation and putrefaction were due to microscopic living organisms raised the question: Whence comes this microscopic life? Do or do not these bodies arise spontaneously in putrescible and fermentable fluids? The results of several investigations were already at hand. Thus Spallanzani (1769) had shown that if a putrescible fluid was hermetically sealed in flasks and the flasks heated in boiling water, decomposition did not occur; Schulze (1836) had obtained the same result by filtering through strong solutions of acids and alkalies the air which entered such flasks, as had also Schwann (1837), by first passing the air through heated tubes; and likewise Schroeder and Dusch (1854) by filtering the air through cotton plugs. All these procedures robbed the air of the suspended microorganisms and, as the fluids had previously been sterilized by heat, decomposition did not occur. But at the time these procedures, though now recognized as the basic principles of bacteriological technique, as applied to sterilization and asepsis, did not gain general credence. "Philosophic argumentation always returned to the fore." The theory of spontaneous generation would not down, and from 1858 to 1862 it was the most important matter of debate in the discussions of the Académie des Sciences.

Pouchet and Pasteur were the disputants, the former defending the thesis that "animals and plants could be generated in a medium abso-

lutely free from atmospheric air, and into which, therefore, no germ or organic bodies could have been brought by the air"; the latter insisting that only through the entrance of such living organisms could the changes in question take place. The discussion lasted several years, and to-day presents many interesting details, but it may suffice to state that it was ended by Pasteur's demonstration that if the neck of a flask was drawn out into a fine tube and bent into a double curve and the flask then heated by boiling, no decomposition occurred. The flask was open to the atmospheric air, but the microorganisms of the air were arrested by the drop of water of condensation, in the lower point of the curved neck. This demonstration, with the later work of Cohn on spores and of Tyndall on floating matter in the air, disposed of the doctrine of spontaneous generation and led to the universal acceptance of Harvey's law *Omne vivum ex ovo,* or as it was modified, *Omne vivum ex vivo.*

It is not surprising that Pasteur at this time foresaw the possibilities in the study of the etiology of the infectious diseases. The process of fermentation, due to living microorganisms, and beginning with a period of apparent inactivity, passing on to a stage of very evident activity and finally sinking gradually into quiescence, was analogous to the period of incubation, the stage of active manifestations and the gradual defervescence of an infectious disease. Also the specificity of the ferments was evidently suggestive of the specific etiology of disease, and altogether we see from several of Pasteur's statements at this time that the relation of microscopic organisms to disease occupied his mind. Thus in a letter to his father, in 1860, he expressed the hope that he may, "bring a little stone to the frail and ill-assured edifice of our knowledge of those deep mysteries of Life and Death where all our intellects have so lamentably failed" and in 1863, after an audience with Napoleon III., he writes, "I assured the Emperor that all my ambition was to arrive at the knowledge of the causes of putrid and contagious diseases."

And now with that peculiar trick of coincidence that is so surprising in the course of culture and inquiry, we find that about this time bacteriology began to make advances along three general lines of study: (1) The etiology of the acute infectious diseases; (2) the prevention of infection, and (3) the achievement of cure or immunity by vaccination. In the first and third of these, Pasteur played a prominent part and it was his work on fermentation which suggested the second to Lister. Pasteur's entrance into the field of etiology and the results he there accomplished form one of the most interesting phases of the history of science and its outcome, a matter of the greatest economic importance to France. The opportunity to study an infectious disease was offered by an epidemic of a mysterious disease which was ruining

the silkworm industry. Whence the disease came or how it was contracted no one knew. Its onset was recognized only by the presence of the little brown or blackish spot from which it got its name (pébrine). Pasteur, who undertook the investigation at the request of his old master Dumas, now a senator, knew nothing of the industry and, as he wrote Dumas, "had never touched a silkworm." But under pressure of Dumas's solicitation he finally yielded, and found himself, a chemist, hitherto interested chiefly in the study of crystallography and fermentation, thrown at once into a new and strange field. That his results were due largely to the training and the point of view obtained through the study of fermentation and the use of the microscope, there can be little doubt, and one is inclined to apply to Pasteur at this stage of his work his own statement of ten years before; "in the fields of observation, chance favors only the mind which is prepared."

Once in the silkworm country he applied himself energetically to the study of the "fatal spots." The story of the complete investigation is a long one, but the main points are that within a month he found that although worms, moths and eggs were infected, the critical stage was the infection of the moths, and that, in these, the infection could be readily demonstrated with the aid of the microscope, and, that having demonstrated this, the remedy lay in using the eggs of non-infected moths only. Thus a new breed of worms free from infection could be obtained and the extension of the disease arrested. In the course of this work he reproduced the disease experimentally by feeding healthy moths with infected mulberry leaves, a novel procedure then, but one, which, with its modifications, was soon to become a commonplace principle of bacteriological investigation. The investigation of the silkworm problem lasted for five years, or until Pasteur cleared up not only the difficulties connected with pébrine, a disease due to infection with a psorosperm, but unmasked also a second disease of the silkworm (flâcherie), a bacterial infection of intestinal origin.

In the meantime Pasteur continued his studies of the diseases of wines (sour, bitter and muddy wines) and invented the process known then and now as "pasteurization." This was the simple process of heating the wine in order to free it of all germs of wine disease and make it suitable for storage and exportation. In this connection he expresses the greatest satisfaction that he was thus able to contribute to the national riches through the practical application of his observations. In 1867 he said:

> **Nothing is more agreeable to a man who has made science his career than to increase the number of discoveries, but his cup of joy is full when the result of his observations is put to immediate practical test.**

The term, pasteurization, is now most frequently heard in connection with milk, but when it is recalled that all commercial and

domestic methods of canning and preserving solid and fluid foods are based on the laboratory experiments of Pasteur one obtains an adequate idea of the importance of his observations and likewise appreciates his satisfaction at the practical application of his methods.

As the silkworm problem began to clear up, Pasteur's thoughts turned more and more to the etiology of the acute infectious diseases of man and animals and their experimental study. This is shown in his appeal to the government (1867) for a laboratory. In this appeal he refers to the advisability of investigating splenic fever and asks, "How can researches be attempted on gangrene, virus or inoculations, without a building suitable for the housing of animals?" and in 1871, in his book on beer, with the diseases of which he had busied himself, we again find a reference to the possibility of the disease of man and animals being due to microorganisms. Here again it is evident that he was influenced by the idea of microorganisms invisibly introduced into fermentable fluids, for in this connection he says, "it is impossible not to be pursued by the thought that similar acts may, *must,* take place in animals and in man"; but without experimental proof he refused to go further.

Pasteur's attack on animal diseases was, however, delayed, first by a cerebral hemorrhage in 1868 which left him partly paralyzed, and then by the Franco-Prussian war which interrupted all scientific efforts in Paris.

Here it is well to pause a moment to consider the attitude of the medical profession towards the theory which was beginning to take shape as the "germ theory." The following decade was to see the bacterial etiology of several important diseases established, Lister's practise of antisepsis in surgery quite generally accepted, and the principle of specific vaccine treatment demonstrated. To-day no phase of medicine is so well understood by the world at large as that of bacteriological principles and aims. Germs and sera, prophylaxis and quarantine, antisepsis and pasteurization, are matters of common knowledge and of ordinary conversation, but it is difficult for one unfamiliar with pre-bacteriology days to appreciate the views which had to be combated only forty years ago. A brief glance at the conditions in 1873 may therefore give you a better appreciation of the events of the succeeding decade. If it is necessary to fix the period, let me remind you that 1873 was the year the University of California removed to its present site.

The Franco-Prussian war had come to a close. Surgeons remembered that though soldiers were killed in battle by tens and hundreds, they died of surgical diseases by thousands.

In the hospitals surgical sepsis ran rampant. Secondary hemorrhage, erysipelas, pyemia and "hospital gangrene" were endemic. Sometimes wards, wings

or whole institutions were closed in vain attempts to stamp out these disorders. (Mumford.)

The causes were unknown and the remedies, therefore, not at hand. Of this period we read with amazement that

Sometimes a surgeon would wear the same old operating coat for years, and would pick waxed ligatures from the button hole of his assistant who carried them there for the convenience of his chief. (Mumford.)

To-day, we refer to it as "a barbarous era," but before Lister the most conscientious surgeon had no reason to do otherwise than has been described.

And, likewise, internal medicine, although it had benefited by improvements in the methods of physical diagnosis and by the application of the principles of pathological anatomy, had made no progress in the prevention and treatment of the infectious diseases. In the presence of these scourges of humanity the physician was not only helpless, but indifferent to the occasional illuminating discoveries of the exact thinker or investigator. Many examples of this indifference are at hand. In the writings of Henle (1840–1853) was announced a rational theory of infection, but it was ignored. Oliver Wendell Holmes (1843 and 1855) had brought forth a great body of facts indicating that puerperal fever was "so far contagious as to be carried from patient to patient by physicians and nurses," and Semmelweis in 1847, working in the old Vienna hospital, had asserted that the mortality from this disease could be reduced from 12 and 16 per cent. to 3 per cent. (later he reduced it to less than 1 per cent.) by the simple procedure of cleansing, in a solution of chlorinated lime water, the hands of those concerned in obstetrical work. The views of Holmes and Semmelweis, however, were ridiculed and the simple antiseptic procedure of the latter was not continued, and when Villemin, thirteen years before Koch discovered the tubercle bacilli, demonstrated by exact experimentation the transmission of tuberculosis to animals, and announced that the disease was a specific transmissible disease, "he was treated almost as a perturber of medical order." I know of nothing which so clearly shows the state of mind of the profession of that day as the remark of Pidoux in criticizing Villemin's work. Referring to the doctrines of specificity he says,

These doctrines condemn us to the research of specific remedies or vaccines and all progress is arrested. . . . Specificity immobilizes medicine.

This representative of traditional medicine could see no relation between Villemin's experiments in which guinea pigs were brought into contact with the dried sputum of tuberculous patients and Pasteur's theory of germs floating in the air being responsible for the various fermentations.

So, likewise, it was with Davaine's demonstration (1863) of bacteria

in the blood of animals dying with anthrax. His view that these micro-organisms, multiplying rapidly in the blood, were in their action analogous to Pasteur's ferments and responsible for the death of the animal, was received only with arguments and did not immediately stimulate investigation, despite his proof of experimental production of the disease by inoculation. To us, who know to-day the fruits of the study of specific etiology and specific therapy, the opposition to the views of Villemin and Davaine and others is almost incomprehensible, but it must be remembered that these views were the fruits of a new type of investigation in practical medicine, that of laboratory research which came close to the sacred precincts of the clinic. "This was the time," in France at least, "when the 'princes of science' or those who were considered as such, were chiefly physicians. The almost daily habit of advising and counselling" gave them a haughty superiority, and views not based on clinical researches were set aside as unsound. Physiology and chemistry applied to the normal individual were well enough, and pathological anatomy with the post-mortem room as an adjunct to the clinic was very proper, but for the laboratory investigator to invade the clinic and present his views concerning the cause of disease or to explain its phenomena was another matter. A well-known surgeon of that time stated:

> Laboratory results should be brought out in a circumspect, modest and reserved manner, as long as they have not been sanctioned by long clinical researches.

But at the very time (1873) of this statement, the forces which were to make the era of laboratory research the greatest of medical eras were already at work; Hoppe-Seyler was establishing (1872) the first laboratory of physiological chemistry, v. Recklinghausen was studying the wanderings of the white blood cell, Weigert was staining bacteria with carmine, Ehrlich was applying dyes to the study of the cells of the blood (both later developed the use of the aniline dyes in histological and bacteriological technic), Abbe was developing his condensing system of illumination for the microscope, Cohn was classifying bacteria according to their morphology, Klebs was separating bacteria from their culture fluid by filtration through animal cells, Pettenkoffer was studying the relation of water to epidemics of typhoid fever and cholera, Obermeier had found a parasite in the blood of relapsing fever, and Koch, a country physician, was carrying on those early researches which were soon to make him the leader in the science of bacteriology. At the same time (since 1866), pathologists (Rindfleish, v. Recklinghausen, Waldeyer, Birch-Hirschfeld and Klebs) had been examining individuals dying of septicemia, pyemia, erysipelas, abscess, inflamed wounds, etc., and had found bacteria in all these lesions, Birch-Hirschfeld, moreover, had called attention to the resemblance, in

pyemia, between the bacteria of the local lesion and those in the internal organs, and had observed bacteria within the leucocyte. To us, who view these activities in retrospect, they are phases of a general advance, the culmination of which is common knowledge, but in the early seventies they were merely the non-related efforts of individual workers. Some practical demonstration was necessary to give to the newer type of laboratory work an importance which would impress the profession. Such a demonstration came through Lister's antiseptic treatment of wounds and was followed shortly by the observations of Koch on anthrax, and of Pasteur on vaccination against bacterial disease.

Lister's first publication concerning his treatment of wounds was in 1867, but it was not until the late seventies that his views were quite generally accepted. In the meantime his methods and their results served to concentrate attention on bacteria and their relation to the diseases of man. He regarded wound infection as putrefaction due to the invasion of the wound by minute microorganisms of the air; a conception which, as he acknowledges in his first publication, was suggested by Pasteur's work on fermentation. In a letter to Pasteur in 1874 he offers "most cordial thanks for having demonstrated to me the germ theory of putrefaction, and thus furnished me with the principle upon which alone the antiseptic treatment can be carried out."

His method was to combat this air-borne infection with an antiseptic—carbolic acid. He cleaned a wound by wiping it out with carbolic acid and then sealed it with lint soaked in this acid. All instruments, sponges and dressings coming in contact with the wound or the hands of the operator or assistants, as well as the site of operation, were cleansed in the same way. Also, by means of a vaporizer, carbolic acid was sprayed into the atmosphere about the site of operation. As years passed the details of this method changed. We now speak of the suppuration of wounds, not of putrefaction; the carbolic spray has been abandoned and our ideas about sepsis have been modified in several ways, but the principle remains as Lister conceived it. The beneficial results of this new treatment in Lister's hands were immediate, but its general application came slowly. We find Pasteur in 1874 referring to Lister's "marvellous surgical methods" and recommending to the surgeons of Paris the use of instruments and dressings sterilized by heat. The complete acceptance of Lister's principle would appear to correspond to the year 1883, when he was made a baronet.

The benefits of antisepsis are now so familiar to us, and its use so much a matter of routine, that we cease to wonder at the revolution it brought about in surgery. Some diseases, as hospital gangrene, it has abolished entirely; others as the septic surgical diseases of former days have been reduced almost to nil; it has robbed the period of child-bearing of one of its chief perils, and has opened to surgery regions and

cavities of the body previously closed on account of the great mortality due to sepsis. Antisepsis shares with anesthesia, as its discoverer, Lister, shares with Morton, Warren and Simpson, the honor of the great advances surgery has made in the treatment of disease and injuries of the abdomen, thorax and the cranial cavity. Who can compute the relief from suffering and the saving of life which may be traced through Lister to Pasteur's laboratory experiments on fermentation?

The recognition of the principle of asepsis by the surgeons was, then, as we have seen, slow and grudging enough; among the profession at large the theory of infection as applied to acute diseases gained more slowly still. It was not until 1880 that advance in the knowledge of the bacterial etiology of infectious diseases assumed such definite shape as to attract general attention. As we look back upon this early work we see clearly that one reason for this slow advance was the absence of proper methods of isolating bacteria in what we now call pure cultures. Pasteur and his co-laborers made (1) direct search for bacteria in the secretions, blood or tissue juices, or (2) inoculated fluid media or animals with such material. By the first of these methods it was possible to recognize bacteria if they were especially abundant, as in anthrax, and it was by this method that Neisser discovered the gonococcus (1879) and Hansen the leprosy bacillus (1879), bacteria which are particularly abundant in the local lesions of the respective diseases. The second method, the use of fluid media, was satisfactory if the material for study contained only one type of organism; if more than one it was obviously difficult to study the life history of a bacterium or to obtain exact results by the inoculation on account of the simultaneous growth of associated or contaminating organisms. This difficulty was overcome by Koch, in 1881, through the introduction of solid culture media. Koch had already, while a country practitioner, definitely and clearly established the relation of the anthrax bacillus to the splenic fever of cattle and had demonstrated in this organism the formation of spores and their importance; also he had published most important observations on the bacteriology of wound infection. The use of solid media, which it is said was suggested to Koch by the growth of mould on potato, led at once to rapid advance, for as each bacterium placed on a solid medium causes, as it multiplies, the growth of a visible colony, it was possible to distinguish colonies having different characteristics and by transplantation to secure pure cultures. The demonstration of Koch's solid media and plate method at the Congress of Hygiene in London in 1881 caused Pasteur to exclaim "C'est un grand-progrés." This advance and the use of microscopes equipped with the oil immersion lens and the Abbe condenser, and the increased knowledge concerning the use of the aniline dyes for staining purposes gave

to bacteriology the technique necessary for its rapid development. Koch was called to the Imperial Board of Health in Berlin in 1880, and started the first laboratory founded for the study of bacteriology and public health problems. In this laboratory, methods of studying and photographing bacteria were developed, methods of disinfection based on the knowledge of spore resistance were elaborated, and the study of the bacteriology of individual diseases inaugurated. As a result of the latter activity, he announced, in 1882, the discovery of the bacillus of tuberculosis, and it is not too much to say that his announcement astounded and profoundly stirred the entire civilized world. In the same year Löffler and Shütz announced the discovery of the bacillus of glanders, and Pasteur published an account of the bacteriology of swine erysipelas; this was the beginning of an active period with discovery crowding on discovery. In 1883 came Koch's announcement of the comma bacillus as the cause of cholera; in 1884 Löffler's description of the bacillus of diphtheria and Nicolaier's discovery of the bacillus of tetanus. So the march of discovery continued until the roll of diseases of known etiology in a short time included typhoid fever, pneumonia, meningitis, influenza, bubonic plague and the various surgical suppurations.

The rapid discoveries of disease-producing microorganisms established definitely Pasteur's doctrine of specificity as applied to etiology and led at once to an interest in public health measures which increased as the years passed, until now it has become one of the most vital interests of our social system. Even in the early eighties, with a knowledge of the etiology and mode of transmission of a few diseases and of Lister's results in antiseptic surgery, it was possible to postulate general prophylactic measures safeguarding the individual and the community, and as knowledge of etiology and transmission increased, so did prophylaxis. Hygeia was again enthroned and it was recognized that "an ounce of prevention is worth a pound of cure."

But prophylaxis was not entirely satisfying. If a specific etiology, why not a specific therapy for bacterial diseases? Men remembered inoculation for smallpox introduced into England by Lady Mary Wortley Montagu early in the eighteenth century. This procedure, the inoculation of healthy individuals with material from the pustules of those ill with a mild form of smallpox had materially reduced the fatality of the disease. The procedure, it is true, had been made illegal in England in 1840, because of the greater success and less danger of Jenner's wonderful discovery (1798) of vaccination with the fluid of the pustule of cowpox. Inoculation, however, despite the fact that it sometimes caused severe and fatal cases of smallpox and perpetuated foci for the dissemination of the disease, had demonstrated that the mild inoculation disease usually protected against the more severe forms. That

Jenner's vaccine was a transmitted cowpox did not militate against the general theory of protecting the individual against a severe form of a disease by the production of a mild form, for cowpox was generally considered to be smallpox modified by passage through another host, the bovine animal. If such results could be obtained against a disease, small-pox, the causal agent of which was unknown, how much easier to vaccinate against a disease of known etiology!

This was therefore the first line of attack in the battle for a specific therapy of the infectious diseases. Already Pasteur was at work. An epidemic of chicken-cholera, in 1880, offered the opportunity for extended experiments. In the course of this work, a chance observation gave him the clue to vaccination with bacteria of attenuated virulence. It had been his routine practise in the experimental production of chicken cholera to use fresh 24-hour cultures; these always produced the disease readily. But in the course of the work it happened that an old culture which had been set aside for a few weeks and forgotten, was used, with the unexpected result that the inoculated hens, although ill for a while, promptly recovered, and what was more surprising, remained refractory to subsequent inoculation of fresh cultures, though the same cultures were virulent for untreated hens. This phenomenon, the attenuation of virulence due to artificial cultivation, Pasteur used as the basis of a treatment by vaccination, which had the immediate effect (1880) of reducing the mortality of chicken cholera to one per cent. and the more remote but far more important effect of stimulating the study of specific therapy. Incidentally it was the link between Lady Mary Wortley Montagu's preventive inoculation and Jenner's vaccination, on the one hand, and modern theories of the production of immunity on the other.

The next step was with anthrax, a disease of cattle. The attenuation of chicken cholera virus had been due to artificial cultivation, but about this time Toussaint, of the veterinary school of Toulouse, made some observation on the attenuation of anthrax bacilli under the influence of increased temperature (heating to 55° C. for ten minutes). His observations, however, were without constant results. Pasteur, who was familiar with Toussaint's work, took up the matter and after a thorough investigation found that anthrax bacilli cultivated at a temperature of 42° to 43° C., became attenuated, and this attenuation persisted on artificial cultivation (1881). The inoculation of such organisms did not cause anthrax, and when later virulent bacilli of anthrax were inoculated, the animals were found to be immune. This was the scientific basis of the celebrated public test at Melun. Sixty sheep and ten cows were placed at the disposal of Pasteur; twenty-five of the sheep and six of the cows were to be vaccinated with attenuated anthrax bacilli, and after an interval of twelve to fifteen days this was to be

repeated. Later this lot, and also twenty-five untreated sheep and four untreated cows, were to be inoculated with a virulent culture of anthrax bacilli. Ten sheep were to have no treatment at all. "The twenty-five unvaccinated sheep will all perish," wrote Pasteur, "the twenty-five vaccinated ones will survive." This magnificent faith based on exact experimentation was justified. All happened as Pasteur predicted. For medicine a new era was at hand; Huxley, in 1880, estimated that the money value of the results of Pasteur's vaccination treatment was sufficient to cover the war indemnity paid by France to Germany in 1879. As the years go by and the influence of Pasteur widens the horizon of preventive medicine and the treatment of disease by immunizing methods, civilization's indebtedness to Pasteur is almost beyond the grasp of the imagination.

His discoveries in vaccination against swine erysipelas and hydrophobia are as fascinating, in their "mingling of experimental skill and scientific imagination" (Herter), as all that he did before. But while Pasteur is an engaging figure, worthy of much more than this simple lecture that we are devoting to him, yet he is not the whole story, and at this point we must turn away from him and proceed to another line of advance: one, however, which was in part the result of his genius and his indefatigable labor. This, the discovery of antitoxic sera, will be discussed in the next lecture, in connection with other modern problems and methods in medical research. But here let me remind you that it was Pasteur, afflicted at the age of 46 with a hemiplegic paralysis—which, by the way, left its traces during the remaining twenty-five years of his life—who said,

> Work can be made into a pleasure, and *alone* is profitable to a man, to his country, to the world.

It would be difficult to find in any field of human endeavor an individual whose life and labors exemplified this precept better than do the life and labors of Louis Pasteur.

TRINIDAD AND BERMUDEZ ASPHALTS AND THEIR USE IN HIGHWAY CONSTRUCTION

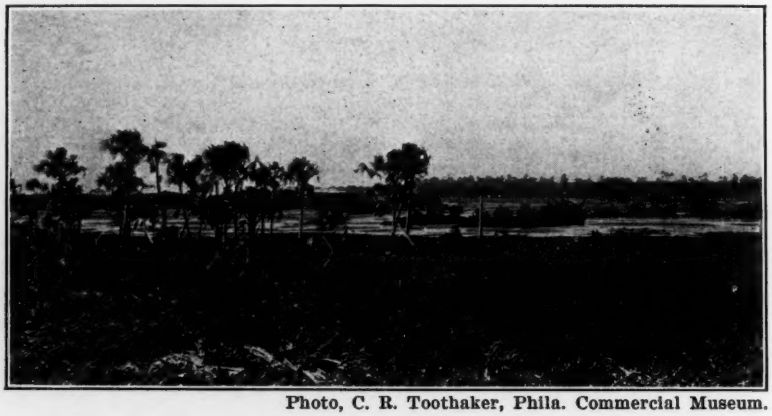
By CLIFFORD RICHARDSON, M. Am. Soc. C. E.
NEW YORK CITY

BITUMEN in its various forms is widely distributed in nature, as natural gas, petroleum, maltha, asphalt and other solid forms. Of the deposits of asphalt which are of great industrial importance there are two which have attracted world wide attention, the so-called Trinidad Pitch Lake and the Bermudez Pitch Lake, the name lake being applied to them very naturally, as they consist of a great expanse of more or less mobile character, covering many acres, and resembling in many ways a similar expanse of water. It is proposed, in the following pages, to give an account of these remarkable deposits, the manner of exploiting them and their industrial applications in highway construction.

The Trinidad Pitch Lake

The Island of Trinidad lies off the north coast of South America, between 10° and 11° of latitude and 61° and 62° longitude. It is bounded on the north by the Caribbean Sea, on the east by the Atlantic, on the south by a narrow channel, into which flow the waters of the northern and most westerly mouths of the Orinoco, and on the west by the Gulf of Paria, the two latter bodies of water separating it from the mainland of Venezuela.

It is of an irregular rectangular shape, with promontories extending from its southwestern and northwestern corners which are several miles in length, between which and the mainland are the narrow straits known as the Dragon's and Serpent's Mouths. These promontories from a large portion of the northern and southern boundaries of the shallow rectangular Gulf of Paria, whose outlets to the ocean are through the Dragon's and Serpent's Mouths. The island has an average length of 48 miles and breadth of 36, containing about 1,750 square miles, and being about one fifth the area of the state of Vermont. It is, as a whole, a flat country, with a high and striking mountain chain descending abruptly into the sea along its northern shore, and with low central and southern ranges of less importance. Its coasts are naturally abrupt on the north, consist of low bluffs on the south and are flat on the east and west. The only harbors are on the western coast.



Photo, C. R. Toothaker, Phila. Commercial Museum.

TRINIDAD PITCH LAKE.

The shape and structure of the long promontories which have been mentioned reveal the fact that Trinidad is, structurally, intimately connected with the mainland. This is proved by the geology and fauna of the island, the latter corresponding closely to that of the mainland and the geological structure being a continuation of that of the continent. Its climate is entirely tropical and somewhat different from that of the remaining Antilles in this respect.

Trinidad was discovered by Columbus on his third voyage in 1498 and taken possession of in the name of Spain, which colonized it about ninety years after. In 1797 it was taken by Great Britain, and has remained since then one of her most important West Indian colonies, and the second in size.

The Island of Trinidad, while not directly connected with the chain of islands of volcanic origin known as the Windward or Caribbean Islands, is directly on the great line of volcanic disturbances running from these to the continent of South America and its volcanic regions. Many of the Windward Islands are still possessed of active vents, so that Trinidad may be looked upon, with its thermal springs and pitch deposits, as being situated at the lowest point between the mountainous volcanic chains of the West Indies and those of South America. More than two thirds of the surface is of Tertiary or recent origin, including the entire southern portion, where the pitch deposits are located. The formations consist of clay, loose sand, shales, limestones, calcareous sandstones, indurated clays, porcelainites of brilliant colors, with pitch deposits here and there. The beds have been considerably disturbed and have at times a large dip. In a series of sands, clays and shales lies the pitch lake.

While there are deposits of pitch scattered all over the island, the only ones of commercial importance are those situated on La Brea Point,

in the wards of La Brea and Guapo, in the County of St. Patrick, on the western shore of the island. They are about 28 miles in an air line from Port of Spain, the seat of government, the chief harbor and only port of entrance, and lie on the north shore of the southwestern peninsula, the point on which they are situated being apparently preserved from destruction by the sea, which is elsewhere rapidly wearing away the coast, by the bituminous deposits which exist along the shore and even some distance from it, and which from their toughness resist the action of the waves better than the soft rocks of this region. The pitch deposits are found scattered over the point, but can be divided conveniently into two classes, according to their source.

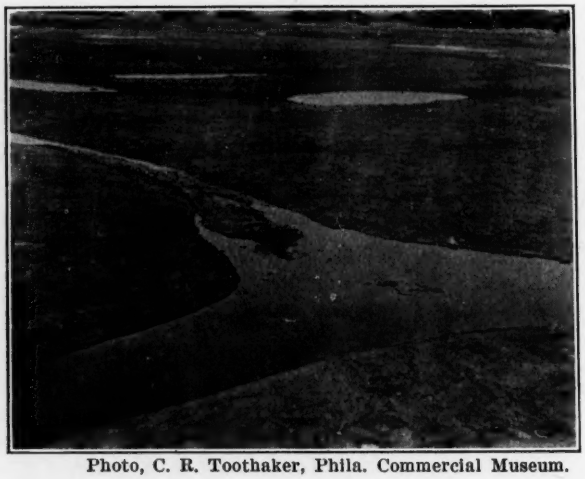
The main deposit is a body of pitch known as the pitch lake, situated at the highest part of the point. Between this and the sea, and more especially toward La Brea, are other deposits, covered more or less and mixed with soil. The pitch from these sources is classified as "lake pitch" and "land pitch."

By far the largest amount of pitch is found apparently in the pitch lake, a nearly circular area of 114.67 acres, 138-feet above sea level. From the lake the ground falls away on all sides, except, perhaps, a slight ridge to the east and southeast, in fact, it seems plain that this deposit lies in the crater of a large mud volcano which has been filled up with pitch.

In past times the pitch very probably continued to collect until it overflowed the rim of the crater, particularly toward the north, and thus perhaps became the source of some or all of the land pitch deposits now found between the lake and the sea.

Photo, C. R. Toothaker, Phila. Commercial Museum.

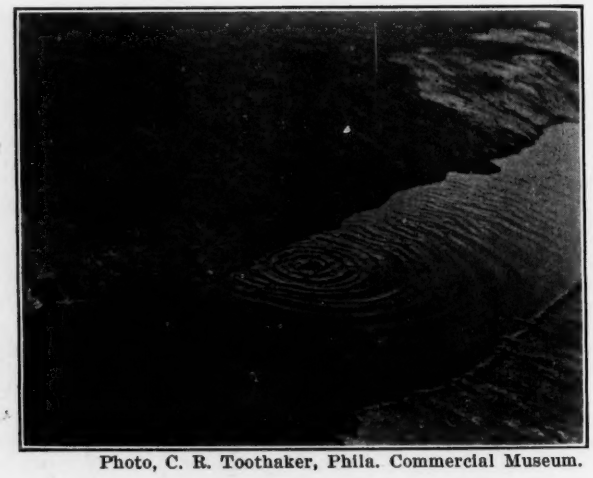
BORDER OF LAKE.



Photo, C. R. Toothaker, Phila. Commercial Museum.

SOFT ASPHALT RISING THROUGH WATER.

The surface of the deposit or lake is not a uniform expanse of pitch. It is grassy along the edges and becomes free from vegetation at some distance from the center. Shrubs and small trees occur in a few cases known as islands. These patches move from place to place with the movement of the pitch at the surface. The main mass of asphalt is a broad expanse of pitch made up of separate areas of irregular outline, but at times quite circular, which are separated by channels, filled with rain water, which prevents their coalescence. The boundaries are depressed and the center of the areas is always somewhat elevated above the edges, that is to say, they are mushroom-like. The origin of the separate areas evidently lies in the constant movement of the crude material, due



Photo, C. R. Toothaker, Phila. Commercial Museum.

EVOLUTION OF GAS IN WATER.

to the evolution of gas at the center, from which point the pitch rolls over toward the edges. This is shown by the fact that pieces of wood which emerge erect at the center are gradually carried to the circumference, their deflection from the perpendicular increasing as the distance from the center increases. At the channel they topple over and are again engulfed in the pitch. This illustrates very well the activity of the entire surface of the deposit, although it is much more active near the center of the lake.

As to the depth of the lake, borings made in 1894 at the center, were carried to a depth of 135 feet, by means of a wash drill, the entire distance being through asphalt of the same character as that at the surface. This result shows the great depth of the crater, and the uni-

Photo, C. R. Toothaker, Phila. Commercial Museum.

FLAKING OUT THE PITCH.

formity of the material which it contains. At the pitch lake, therefore, at a point 138 feet above the sea, there is a bowl-like depression, more than two thousand feet across, and over 135 feet deep, reaching to the sea level, and filled with a uniform mass of asphalt, a mass which must amount to many million of tons, making it the largest deposit of solid native bitumen in the world.

The material forming this deposit is an emulsion of water, gas, bitumen and mineral matter, the latter consisting largely of fine sand and a lesser amount of clay. It is in constant motion, owing to the evolution of gas, and for this reason whenever a hole is dug in the surface, whether deep or shallow, it rapidly fills up, and the surface resumes its original level after a short time. While sufficiently soft to accommodate itself to any change of level and to slow movement, it can be readily

flaked out with picks, in large conchoidal masses weighing from 50 to 75 pounds. It is honeycombed with gas cavities, and resembles in appearance the structure of a Swiss cheese. The gas evolved by the pitch consists of hydrogen sulphide and carbon dioxide, but in such proportions that it burns readily when a match is applied, although the flame is not maintained for any length of time.

In the center of the so-called lake is a point where there is a continued influx of soft material, accompanied by a stronger evolution of gas, which gradually hardens and becomes like the remainder of the deposit. The point of evolution of the soft material moves about from

Photo, W. H. Rau, Philadelphia.

WINNING THE CRUDE PITCH, REFINERY IN DISTANCE.

place to place along lines of least resistance. As that evolved at one point hardens the fresh material breaks out elsewhere. It is peculiar in that it is associated with so much free water which rises with it, that it can be handled freely and made into a ball without adhering to the hands. It is in an active state of change, since if it is sealed in a tin can the gas evolved will, in a few weeks, burst the containing vessel.

The temperature of the pitch at the surface is no greater than that of the surrounding air except when it is exposed to the noon-day sun, when it may rise to 130° F. or over. That of the soft pitch is no higher than any other part of the deposit.

Photo, C. R. Toothaker, Phila. Commercial Museum.

LOADING THE CRUDE PITCH ON CARS.

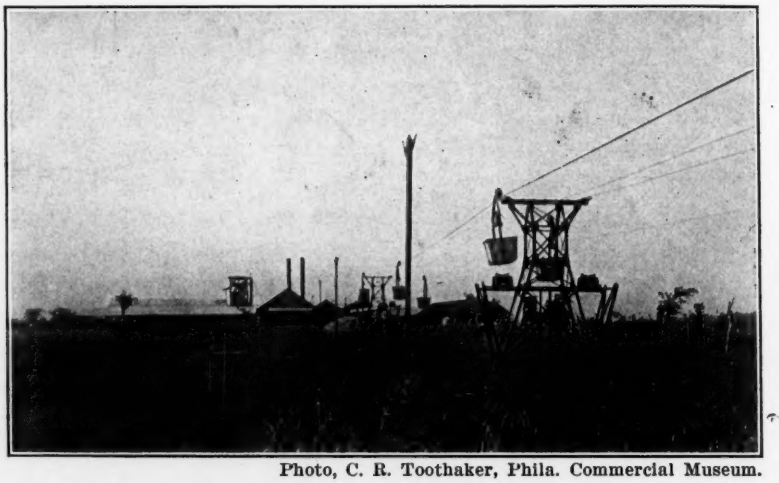
	Crude Per Cent.	Dry Per Cent.
Water and gas, volatilized at 100° C.	29.0	
Bitumen soluble in cold carbon disulphide	39.0	56.5
Bitumen retained by mineral matter	.3	.3
Mineral matter, on ignition with tricalcium-phosphate	27.2	38.5
Water of hydration in clay and silicate	3.3	4.2
	98.8	99.5

COMPOSITION OF THE ASPHALT

An examination of the asphalt shows that it is one of extreme uniformity in composition. It consists of, according to the most refined methods of analysis, from whatever part of the deposit it is taken:

Photo, C. R. Toothaker, Phila. Commercial Museum.

LOADING THE CRUDE PITCH ON CARS.



Photo, C. R. Toothaker, Phila. Commercial Museum.

TRANSPORTATION OF PITCH BY AERIAL CABLE FROM REFINERY TO PIER.

The average composition of samples taken on circles 200, 400, 600, 800, 1,000 and 1,100 feet from the center of the deposits, and for the average material from the entire depth of the boring, as determined by routine methods, was found, after drying the material to free it from the water which is present, to be as follows:

AVERAGE COMPOSITION OF TRINIDAD LAKE PITCH IN CIRCLES

	Bit. by CS_2, Per Cent.	Mineral Matter, Per Cent.	Organic not Soluble, Per Cent.	Soluble in Naphtha, Per Cent.	Total Bitumen thus Soluble, Per Cent.
Circle 2, 200 ft. from center.....	55.02	35.41	9.57	31.83	57.85
Circle 4, 400 ft. from center.....	54.99	35.40	9.61	31.63	57.55
Circle 6, 600 ft. from center.....	54.84	35.59	9.67	31.85	58.26
Circle 8, 800 ft. from center.....	54.66	35.56	9.78	31.67	57.97
Circle 10, 1,000 ft. from center..	54.78	35.44	9.78	31.58	57.64
Circle 12, 1,100 ft. from center..	54.62	35.45	9.93	31.77	57.51
General average.....	54.92	35.46	9.72	31.72	57.79
Circle 14, 14,000 ft. from center.	53.86	36.38	9.76	30.52	56.66

The great uniformity of the deposit is revealed by these figures.

The water is probably of thermal origin, as it contains borates and iodides. Chlorides and sulphates of sodium are the predominating salts, sulphate of ammonia in marked amount, while chloride of potassium, lime and magnesium and ferrous iron are present. It is impossible to separate the water from the bitumen without change, but in the old methods of refining pools of it would collect on the surface of the asphalt, and this water, although somewhat concentrated and oxidized, had the following composition:

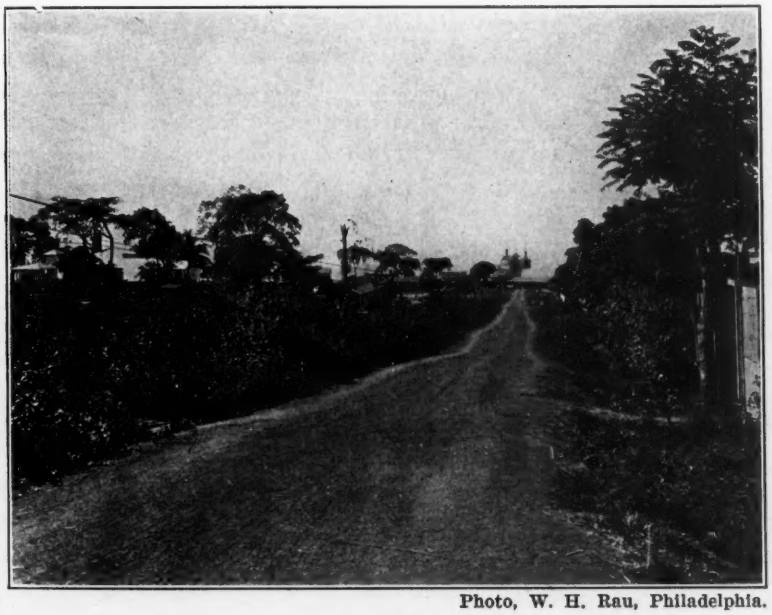
ANALYSIS OF ASPHALT WATER

Specific gravity 1,017 · 15° C./15° C. Reaction strongly acid
In 1 kilogram

Cl	6.7757	NH_4	.4071
SO_3	5.5409	K	.3391
SO_2	.0467	Li	.0271
S_2O_7	Traces	Ca	.5280
H_2S	Traces	Mg	.2666
S	Traces	Fe	.0720
SiO_2	.0688	Al	Trace
B_2O_3	.0117	Mn	None
I	.0008	Cs and Rb	None
Br	Trace	Organic	.4901
P_2O_5	None	Oxygen	——
Na	6.5149		21.0896

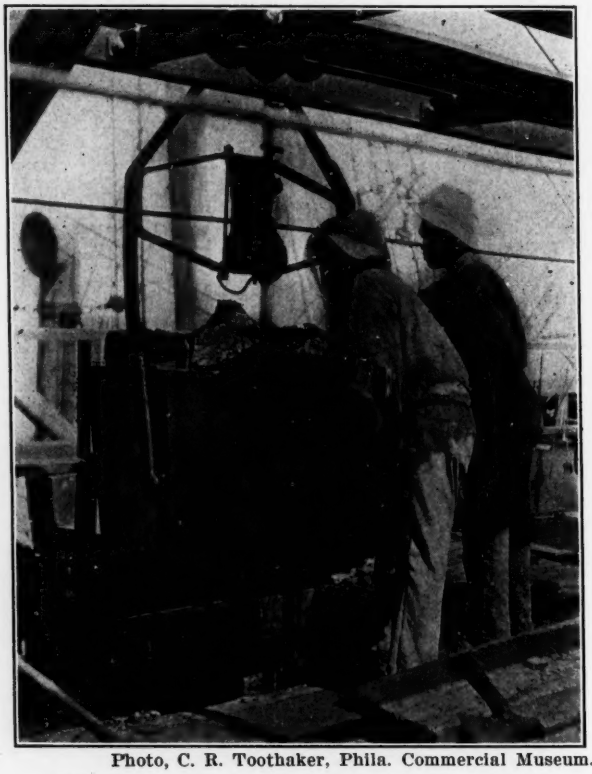
The percentage of soluble mineral matter or salts as compared to that of the bitumen is extremely small and unimportant, and plays no part in the behavior of the material industrially, since the addition of the same salts to other asphalts has been found to produce no perceptible effect upon them.

For many years Trinidad asphalt was supposed to contain a considerable amount of organic matter not of a bituminous nature, but an investigation conducted by me in 1908 showed that this really consists



Photo, W. H. Rau, Philadelphia.

ROAD FROM LAKE TO PIER, PIER IN DISTANCE.



Photo, C. R. Toothaker, Phila. Commercial Museum.
DUMPING CRUDE ASPHALT INTO HOLD OF VESSEL.

of the water of hydration of the clay forming part of the mineral matter, which was lost on ignition after the removal of the bitumen by solvents, and that, as a matter of fact, there is practically nothing of the nature of the organic matter not bitumen which has heretofore been attributed to Trinidad asphalt.

In direct contrast to this acid water is that which rises with the soft pitch in the center of the lake, which is alkaline in reaction, and has the following composition:

	Grams per Kilo
Specific gravity	1.0599
Solids at 110° C.	82.100
Sodium, Na	27.193
Potassium, K	0.528
Chlorine, Cl	38.210
Sulphuric acid, SO_3	3.207
Calcium oxide, CaO	Trace
Magnesium oxide, MgO	0.506
Carbonic acid, CO_2	3.700
Silica, SiO_2	0.222
Organic matter	?
	73.566

The emulsified water can be removed from the crude Trinidad asphalt by grinding it to a fine powder and exposure to the air, or by heating the material to a temperature above the boiling point of water, and until the bitumen melts. Upon the latter fact is based the process of refining which is used industrially, and which will be described later.

The bitumen of Trinidad asphalt can be separated from the mineral matter by solvents, and thus prepared is a brilliant, glossy, pitchlike substance, which has a semi-conchoidal fracture when struck a sharp blow, but which yields to gentle pressure and slowly flows at summer temperatures. It softens at 76° C., flows quickly at 83° C., but is not liquid until a temperature is reached which is above 100° C. It has a specific gravity, when entirely free from mineral matter, of 1.032 at 25° C.

Its ultimate composition is

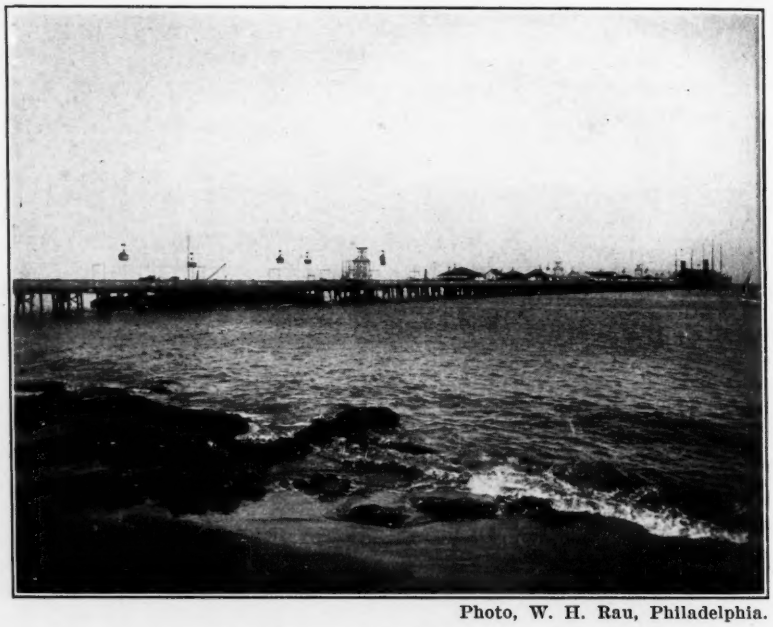
Carbon	82.33
Hydrogen	10.69
Sulphur	6.16
Nitrogen	0.81
	99.99

It is noticeable that this bitumen is characterized by the large percentage of sulphur which it contains, by the presence of nitrogen, and by the absence of oxygen.

It is to the sulphur which is present, as will be shown later on, that the valuable properties of the Trinidad bitumen are to be attributed.

Photo, C. R. Toothaker, Phila. Commercial Museum.

PIER WITH CRUDE ASPHALT IN BUCKETS.



Photo, W. H. Rau, Philadelphia.

PIER AT BRIGHTON, TRINIDAD, FROM SHORE.

It consists, like all the other more or less solid native bitumens, of components of two different classes, which can be separated by solvents;

Photo, C. R. Toothaker, Phila. Commercial Museum.

PITCH CONES ON EDGE OF TRINIDAD LAKE.

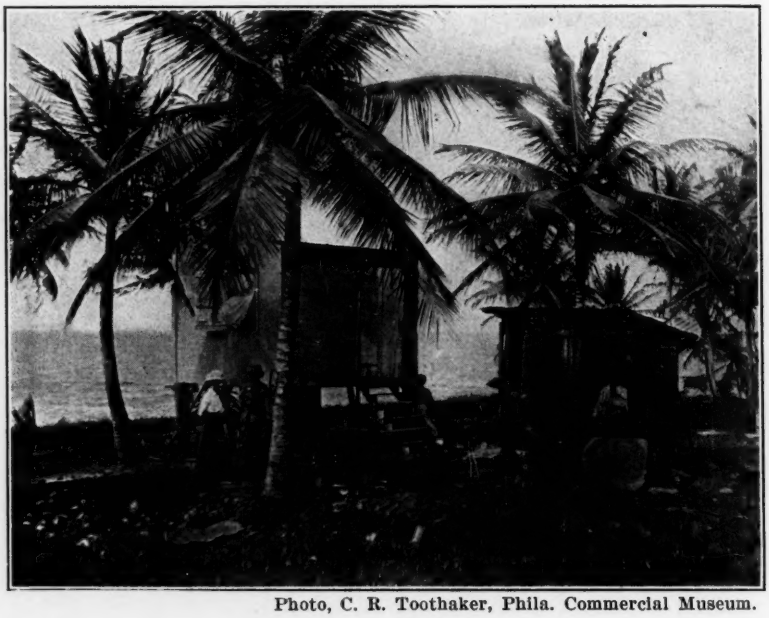
those which are soluble in light petroleum naphtha, and the remainder which are insoluble, although the percentage will depend to a certain extent on the character of the solvents. The softer or oily portion which is soluble in naphtha is, for 88° naphtha at air temperatures, about 63 per cent. The components of Trinidad asphalt and of other bitumens, which are thus soluble, have been denominated by the writer "Malthenes," a name to be applied to this class of hydrocarbons, not as representing any homogeneous entity, but merely descriptive of their general character. The term petrolenes has also been used to cover this same class of material.

Photo, C. R. Toothaker, Phila. Commercial Museum.

PLANTATION BUILDINGS, TRINIDAD.

The hydrocarbons and their derivatives which are insoluble have been called asphaltenes.

The malthenes of Trinidad asphalt are distinguished by the fact that they are of an extremely sticky and cementitious nature, and not merely oily as is often the case with material of similar consistency prepared from petroleums. The value of any bitumen or combination of bitumens for highway construction depends on the character of the malthenes of which it is composed, and the relative proportion of these to the asphaltenes. Where the former are not present in sufficient amount, it is necessary to add to the asphalt material in which malthenes predominate to attain a proper consistency. This is known as fluxing the asphalt, and in the case of that of Trinidad, owing to the presence of the large amount of malthenes of a sticky nature, it can be accom-



Photo, C. R. Toothaker, Phila. Commercial Museum.

LABORER'S QUARTERS, POINT D'OR.

plished by the use of any of the fluxes that are available, even those of a paraffine nature, since the paraffine hydrocarbons, containing a considerable per cent. of paraffine scale, combine with the malthenes of the Trinidad asphalt to produce a satisfactory binding material. If the malthenes were not present to the extent in which they are found, it would be necessary to use an asphaltic flux, as for example in fluxing the harder bitumens, such as gilsonite and grahamite.

While the malthenes give to the asphalt its cementitious property, the asphaltenes impart cohesiveness as distinguished from adhesiveness, and supply body and stability to the binding material. It has been found that asphalt cement, that is to say, a solid asphalt combined with a suitable flux, must contain not less than 15 per cent. of asphaltenes or will otherwise lack cohesiveness and stability, while on the other hand, if it contains less than 70 per cent. of malthenes it will not be sufficiently adhesive. Even with the proper proportions of malthenes and asphaltenes a bitumen may still be valueless as a cement, if the malthenes are not of a proper character, that is to say, not sticky and adhesive.

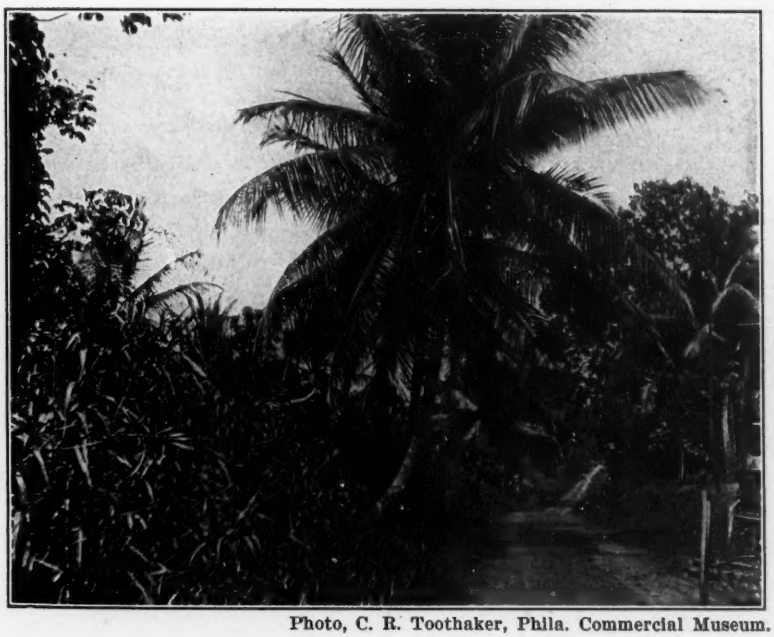
Trinidad asphalt, owing to the character of and proportions in which its components are present, has been found to possess to the highest degree, the properties which are necessary for adhesiveness and stability, and it is to this that we may attribute the fact that it has proved itself to be a standard material with which to compare other bitumens.

Land Deposits

In what has been said hitherto reference was had to the asphalt taken from the lake deposit itself. As has been mentioned, there are deposits of bitumen between the lake and the sea, and the material taken therefrom is known as land pitch. It has been subject to atmospheric weathering and by contact with the soil for years, as a result of which its physical properties are inferior to those possessed by the lake deposit. The greater the distance from the lake at which the land pitch is found, the more it shows signs of age and weathering and the more inferior it is.

Trinidad Petroleum

There has recently been developed on the Island of Trinidad, in the neighborhood of the pitch lake, a new source of binding or cementing material of a very desirable character for surface application to roads, and for the productions of a residual pitch of a high grade. It has been called a liquid asphalt, and must have been the source of the asphalt found in the main deposit, and of the material which now forms the soft spot in the middle of the lake. It was recognized in the earliest days of the Trinidad asphalt industry that the millions of tons of asphalt existing in the old crater must be associated with some mother



Photo, C. R. Toothaker, Phila. Commercial Museum.

A Country Road, Trinidad.

Photo, C. R. Toothaker, Phila. Commercial Museum.

HIGH WOODS, TRINIDAD.

source of bitumen. Long before the asphalt was used on any industrial scale, attempts to reach this and obtain petroleum were made. A comparatively shallow well was sunk not far from the lake, and a heavy liquid asphalt was discovered, but the facilities available at that time for sinking a deep well, and the lack of demand or means of utilizing this material, caused development to be abandoned. Success has now crowned the efforts to obtain this liquid asphalt in commercial quantities, and it is now available for road construction. It has proved to be a most remarkable and unique form of bitumen. Primarily it is, of course, a petroleum, being a liquid form of bitumen coming from a depth of about 900 feet below the surface. Its characteristics as determined by the usual form of distillation proposed by Engler, and generally followed by oil experts, appears from the following data:

Specific gravity at 60° F.	.965
Beaume at 60° F.	15.1°
Flash—open cup	95° F.

Bitumen sol. in CS_2	99.9 per cent.
Bitumen insol. in 88° naphtha	8.3 per cent.
Loss 5 hours 325° F. (20 grams)	24.6 per cent.
Condition of residue	Fluid
Paraffine	None
Viscosity—Engler—212° F.—50 c.c.	34.5 sec.

ENGLER DISTILLATION

Below 302° F.	4.43 per cent.
302–520° F.	20.74 per cent.
Residue above 520° F.	74.53 per cent.
Loss	.30 per cent.
	100.00

This petroleum is truly asphaltic and carries no solid or heavy liquid paraffine hydrocarbons. It is distinguished by the fact that it yields a high percentage of light distillates or "tops" for an oil of such low gravity. The intermediate distillates, those of the lubricating type, are small in amount, while the residue is truly asphaltic resembling that found in the lake deposit, but of course free from mineral matter and water. On this account the oil is peculiarly adaptable to road surfacing work, the light oil carrying the heavier asphaltic portion into the surface and afterwards, on its evaporation under the sun, leaving it there in a most desirable form as a binding agent. If the lighter fraction or "tops" are removed, we have at once an asphaltic oil which is of the most desirable character for hot application, and has the following characteristics:

Specific gravity at 60° F.	.994
Beaume at 60° F.	10.8°
Flash—open cup	200° F.
Bitumen sol. in CS_2	99.9 per cent.
Bitumen insol. in 88° naphtha	10.8 per cent.
Loss 5 hours 325° F. (20 grams)	17.5 per cent.
Condition of residue	Fluid
Paraffine	None
Viscosity—Engler—212° F.—50 c.c.	102.2 sec.

The oil is further distinguished by the fact that it carries a very considerable percentage of sulphur, in the neighborhood of 3 per cent. and it is evident that the sulphur found in the Trinidad crude asphalt is derived, at least in part, from this source. Owing to the presence of this sulphur the oil possesses those desirable characteristics, as a road oil, which the refined Trinidad asphalt possesses as a paving material, and it is for this reason that a road carpet prepared with this liquid asphalt does not become unpleasantly soft when exposed to the sun.

(To be concluded)

THE RÔLE OF THE HOUSE FLY AND CERTAIN OTHER INSECTS IN THE SPREAD OF HUMAN DISEASES[1]

By W. E. BRITTON, Ph.D.

STATE ENTOMOLOGIST, NEW HAVEN, CONN.

THE rapid progress during recent years in the knowledge and treatment of human diseases has been marked by a number of discoveries so important and fundamental in their nature that intelligent people everywhere are paying homage to the discoverers, some of whom have given the best part of their lives for the benefit of others. In no line of scientific activity are the results of recent discovery more far-reaching or have they a more important bearing on the daily lives of men, women and children than in medical entomology—or the relation of insects to the transmission of human diseases.

The diseases that may be spread by insects are of course those that are commonly known as germ diseases, some of which are regarded as contagious or infectious. They are in some cases blood diseases, and affect the entire system, while in others perhaps only one part of the body, or certain organs, are involved. Some, like typhoid fever and tuberculosis, are caused by bacteria, the lowest forms of plant life, and others, like scarlet fever and malaria, by protozoa, which are animals low in the scale of classification. It is manifestly impossible in this paper to place before you all of the evidence, or even brief descriptions of the various studies and experiments which enabled the investigators finally to obtain the facts that make up our present knowledge of the subject. I shall therefore mention only a few of the strategic points and striking illustrations, hoping that these may be sufficient to show the importance of the subject and the necessity for action, and to enlist your interest in it.

The agency of insects in the spread of human diseases is of two sorts—(1) mechanical carriers, (2) essential hosts.

To the first group belongs the common house fly, and whatever germs adhere to the body, feet, tongue or wings of the fly in its perambulations in and over filth, or those that are swallowed by it, may be deposited on food or in other places in such manner as to cause infection.

The mosquito is a good example of the second group. One species, *Anopheles maculipennis,* is one of the necessary hosts in the development of the malarial parasite. Man is the other host, and in the blood

[1] This paper in substance was given, with lantern slides, before the Consumers' League, New Haven, Conn., May 4, 1911. A few paragraphs are taken verbatim from previous papers by the author.

of each host the parasite undergoes a certain development which is essential to complete the life cycle and insure the perpetuation of the malarial organism. Another kind of mosquito, in the tropics, is responsible in a similar manner for infecting human beings with yellow fever.

With these brief introductory remarks, we will now take up a discussion of the house fly and such other insects as are known to carry disease germs.

The House Fly, *Musca domestica*

The common house fly has been associated with typhoid epidemics so frequently during the past few years that Dr. Howard suggests that it be called the "typhoid fly."[2] Even before the rôle of this insect was definitely understood, it was suspected to have a connection with the disease, because typhoid fever is generally most prevalent in late summer, at the time when flies are the most abundant. I do not wish to convey the impression that typhoid is spread only by means of flies, for such is not the case. There are plenty of other agencies, such as a polluted water or milk supply, but flies play a much more important part in this connection than was supposed a few years ago, and the house fly is more important than other species because of its great abundance and its habit of occupying the dwellings of man and crawling over his food.

It was an old idea that flies were not only innocuous but were a benefit to mankind. It is said that Sir John Lubbock provoked a laugh in the House of Commons in 1873 by quoting as follows from one of the books used in the elementary schools: "The fly keeps the warm air pure and wholesome by its swift and zigzag flight."[3]

On the other hand, Kircher,[4] writing in 1658, makes the following statement: "There can be no doubt that flies feed on the internal secretions of the diseased and dying, then flying away, they deposit their excretions on the food in the neighboring dwellings, and persons who eat it are thus infected."

As it took 240 years to demonstrate the truth of this theory, and as twelve years have now passed, and the lesson of the Spanish war has not yet come into general practise, it is a mooted question if, after all, our progress is not an idle boast. At the present day there are many persons who regard flies as a necessary nuisance, but who are not awake to the dangers of their abundance.

As a rule flies do not go far from their breeding places, and if they are very abundant in any locality it is reasonably certain that their breeding place is close at hand.

[2] L. O. Howard, Bureau of Entomology, Bull. 78, p. 23.
[3] G. H. F. Nuttall, Johns Hopkins Hospital Reports, Vol. VIII., p. 37.
[4] W. A. Riley, *Science*, February 18, 1910.

The house fly does not bite, but its mouth parts are fitted for lapping and sucking up liquids. Another fly (*Stomoxys calcitrans*), called the stable fly, pierces the skin, and as this fly resembles the house fly and sometimes enters houses, many persons are mistaken in thinking that the house fly actually bites.

Breeding in filth and visiting all sorts of foul waste and decaying animal and vegetable matter and crawling over it, flies can not help becoming contaminated. At the first opportunity they will also crawl over food in the kitchen and drink from the milk pitcher. In this way some of the germs are rubbed off and adhere to the food and are swallowed with it by human beings. The diseases most commonly disseminated in this manner are those of the alimentary canal known as enteric diseases, such as typhoid fever, cholera and dysentery, the germs of which are voided in fecal matter, which if left exposed is certain to be visited by hundreds of flies, and some of the causative bacterial germs of these diseases are thus transferred to food, and infection is thus made possible. But it is not these diseases alone that may be and are occasionally carried by flies. There is considerable evidence to show that the house fly and its near relatives may carry the anthrax bacillus in their digestive systems and deposit the germs with their excretions, or may carry these germs exteriorly if the flies have visited foul matter containing them. They may then infect persons by crawling over wounds or even food. Flies may carry the germs of tuberculosis by visiting sputum and then crawling over the mouth and nose and food of persons. Nuttall made some interesting experiments in 1897 which proved that house flies not only may carry the germs of bubonic plague, commonly carried by fleas, but that they may actually die of the disease.[5]

It has been shown that the causative germs of some of these diseases may be and are taken into the digestive tract of the house fly and deposited upon food, confections or other substances. Thus the tiny fly specks which are the bane of every good housekeeper may be positively dangerous.

Formerly it was supposed that the house fly bred only in manure from the stables, and that it did breed in such places was pointed out as early as 1834 by Bouché. In 1873 Packard, and in 1880 Taschenberg, published accounts of the house fly showing that it usually breeds in horse manure. Packard records fourteen days as the period required to develop a generation. Dr. Howard in 1895[6] studied the insect, and had some difficulty in rearing it in captivity. The female laid 120 eggs, which hatched in eight hours, and the maggots lived five days before transforming. The pupa or cocoon stage also lasted five

[5] G. H. F. Nuttall, Johns Hopkins Hospital Reports, Vol. VIII., p. 16.
[6] L. O. Howard, Bureau of Entomology, Bull. 4, p. 46, 1896.

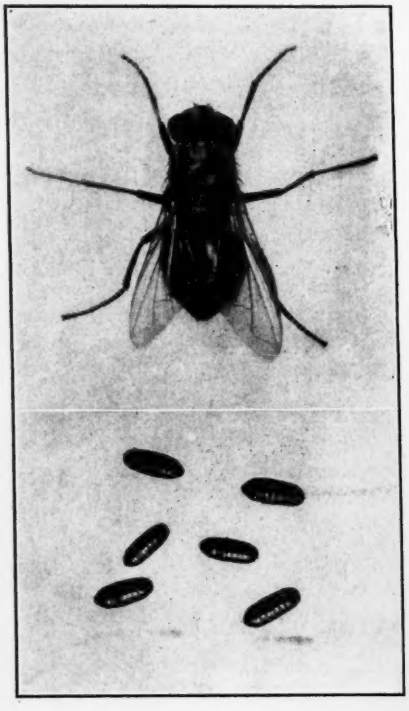
days, making only ten days for the complete life cycle. Dr. Howard considered that probably ninety-five per cent. of all house flies in towns and cities breed in the heaps of horse manure about the stables or in the fields. Later investigations of Dr. Howard and others show that the house fly may breed in privies, garbage cans and garbage heaps, street sweepings, waste from slaughter houses, and even between the folds of old paper from ash dumps. In fact, in almost any place where suitable moisture and food conditions exist.

Notable Typhoid Epidemics

The thoughtlessness of some persons having charge of the sick is described by Dr. Veeder in the New York *Medical Record.*[1] He states that he has seen dejecta from a typhoid patient emptied from a commode and the receptacle left standing without disinfection within a few feet of a pitcher of milk, both attracting flies, which fairly swarmed from one to the other. In the summer of 1898, when our armies were in camp in the southern states during the Spanish war, an epidemic of typhoid broke out. It caused much apprehension and cost many lives. Though the water supply was suspected, the authorities were not able to check the disease by the methods usually practised. Dr. Veeder was one of the first to advance the idea that the germs were being carried by flies, and it was not until the camp had been visited by government entomologists from Washington that the matter was properly controlled. I have the statement from a young soldier who at Chickamauga contracted the disease and was carried to a Philadelphia hospital for treatment, that the sinks or latrines had become filled to overflowing, and were not even covered with dirt, but, reeking with filth and disgusting odors, they attracted vast swarms of flies. It was but a short distance to the mess tents, where flies swarmed just as thickly, and during the investigation that followed, flies were taken from the food with their legs whitened by the lime that had been spread over the sinks. Thousands of soldiers were then encamped, hundreds were sick with typhoid, yet the able men had little or nothing to do, and might just as well have kept the camp in a sanitary condition. It appeared afterwards that the sanitary regulations of the surgeon general had not been followed: the privates dared not complain, the officers in charge were indifferent to this phase of the sanitation of the camp, and the surgeons were all busy administering to the sick and wounded. Such a condition is especially dangerous in view of the fact that in typhoid cases the germs are often given off in the dejecta before the disease has been recognized and before the patient takes to the bed, and also for a long time after recovery seems complete.

Permit me to quote from the official report of Messrs. Reed, Vaughan

[1] H. A. Veeder, New York *Medical Record*, Vol. 54, September 17, 1898.



COMMON HOUSE OR TYPHOID FLY, *Musca domestica*. Enlarged five times. EGGS as they are deposited in horse manure. Natural size.

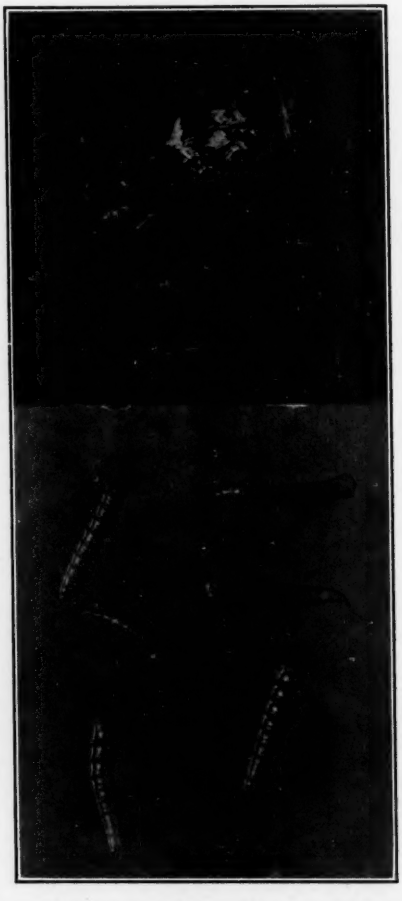
deaths." "Flies undoubtedly serve as carriers of the infection."[8]

In other words, out of 107,973 officers and men in the camps, 20,738 were sick and 1,578 died from typhoid. From the above figures it is evident that flies are more effective destructive agents than Spanish bullets.

According to Dr. Alice Hamilton,[9] the Chicago typhoid epidemic of 1902 was traced largely to the agency of flies.

and Shakespeare, who were appointed to investigate this typhoid outbreak:

"About one fifth of the soldiers in the National Encampment in the United States in 1898 developed typhoid fever." "The percentage of deaths among typhoid fever cases was 7.61." "The deaths from typhoid fever were 86.24 per cent. of the total



PUPARIA and MAGGOTS OR LARVÆ OF HOUSE FLY. Enlarged three times.

[8] Walter Reed, V. C. Vaughn, E. O. Shakespeare, "Report on the Origin and Spread of Typhoid Fever in U. S. Military Camps during the Spanish War of 1898," p. 666.

[9] Hamilton, *Journal of American Medical Association*, 40, 576.

One of the most significant publications in recent years was issued in 1908 by the Merchants' Association of New York City on the pollution of New York Harbor.[10] The fecal matter of the sewerage discharge into the water attracted swarms of flies, many of which were caught in traps placed on the piers and afterward examined in the laboratory for bacteria. One individual fly carried more than 100,000 fecal bacteria. The same publication contains a chart showing the location where each individual death from intestinal diseases occurred during the season, and they were by far the most prevalent in the downtown districts near the water front, where sewerage and fly conditions are worst. Infantile diarrhœa was the cause of many of these deaths, and the author of this publication, Dr. Jackson, attributes much of the infection to the agency of flies.

Washburn only last year[11] investigated a typhoid outbreak, and found flies chiefly responsible for the spread of this disease on the Iron Range of Minnesota. Many other cases might be cited.

Local Conditions to be Avoided

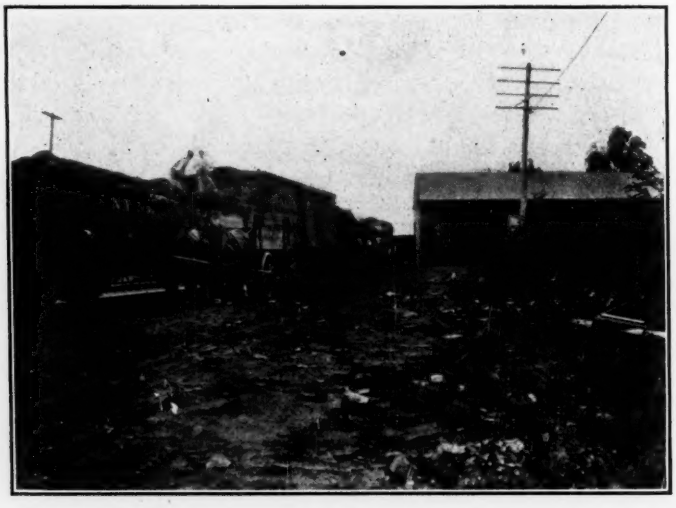
Many persons go from their homes in the cities to spend their vacations at shore resorts or mountain camps, and are soon taken sick with typhoid. The imperfect sanitary conditions at many of these places make it hard to prevent the spread of the disease if a case of it occurs, and where a large number of persons are brought together from different localities there is always danger.

Large gangs of laborers in quarries, lumber camps and on construction work are, on account of carelessness and ignorance, liable to suffer from the spread of typhoid fever by flies, and what has been said of typhoid would doubtless be equally true of cholera and dysentery.

In looking about our cities and towns for breeding places of the house fly, what do we find? In many stables manure is allowed to accumulate untreated as long as there is room for it, then it is carted away to the suburbs and piled upon the land. Carloads of manure from the large cities are drawn through our towns and allowed to stand on sidings for several days, perhaps, before reaching their destination and being unloaded. Streets are often so filthy as to attract flies, and when cleaned, the sweepings are dumped on vacant lots or drawn into the parks for fertilizer and allowed to remain in heaps several months. In many streets water closets are not installed, and uncared-for dry closets are still in use. All of these conditions are favorable for the breeding of flies, and we should remember that in

[10] D. D. Jackson, "Pollution of New York Harbor," Merchants' Association of New York, July, 1908.

[11] F. L. Washburn, Report of State Entomologist of Minnesota, 1909–1910, p. 135. See also Popular Science Monthly, August, 1911, p. 137.



UNLOADING A CAR OF STABLE MANURE FROM NEW YORK. Four ounces of material from the top of this carload contained between 700 and 800 maggots, by actual count.

warm weather only ten days are required to develop a generation. Each female may lay 120 eggs, and her possible progeny amounts to more than 3,000,000,000 in a single season. Hence the tremendous increase in the number of flies the latter part of the summer. Then please visit some of our cheap restaurants and meat markets, and note how they are swarming with flies which crawl all over the unprotected food and provisions. If you must eat food from such a place, choose something that can be cooked thoroughly before eating, or if raw, something that has a natural covering to be removed before eating, like an orange or banana. Remember that typhoid fever does not always come through the water or milk supply or by eating oysters.

Of course flies do not originate typhoid fever, but if a case occurs in a locality where conditions are unsanitary they are sure to spread it.

The stable manure which is shipped in carloads from the cities to suburban or country districts is an excellent breeding place for flies. Two years ago one of my assistants examined such a loaded car standing upon the siding near this city (New Haven). The contents had come from New York and was waiting to be unloaded for use upon the land for growing fruit or vegetable crops. The upper two inches of the manure was literally swarming with maggots. Some of the material was taken to the laboratory, and four ounces of it contained between 700 and 800 maggots, by actual count!

What of ordinances and health board regulations? It is true that anti-spitting rules are in force, as are also regulations about the covering of foodstuffs when carted through the streets or exhibited for sale, and garbage cans and wagons must be covered. Is it unreasonable to

require that exposed surfaces of manure on platform cars or in stables, yards and fields be either screened or treated once a week to prevent the breeding of flies?

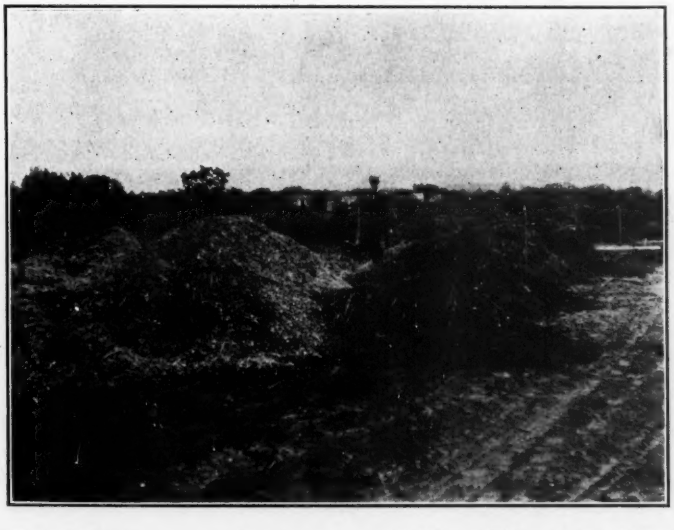
Remedies for Flies

Screen buildings: and prevent flies from breeding.

All living rooms in houses, and especially the kitchen and dining room, sick-rooms, and all hotels, restaurants, markets and stores where food supplies are sold or stored should be fitted with screens to keep out flies.

Breeding places of flies should be abolished where possible by not allowing manure, garbage or filth to accumulate or by screening it to keep flies away, or by treating it to kill the maggots. Manure treated with chloride of lime each day will not produce flies. Kerosene or one of the so-called soluble or miscible oils sold everywhere for spraying orchards will probably kill the maggots if the outer two inches is saturated with the liquid.

Flies in houses may be killed by the use of insect powder, fly-paper, or by five-per-cent. sweetened formalin placed about the rooms in saucers. A recent circular[12] from the North Carolina Agricultural Experiment Station recommends one tablespoonful of commercial formalin (40 per cent.) to a half pint teacup of half milk and half water. The liquid is exposed in a shallow plate with a slice of bread in it to give more space for the flies to alight while drinking. The author of this circular, Professor R. I. Smith, states that in this way



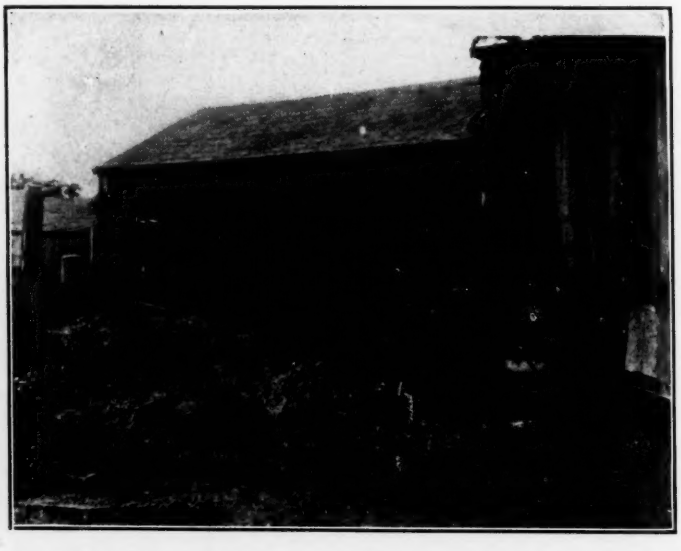
Horse Manure piled in the Suburbs, in a suitable condition to breed many flies.

[12] R. I. Smith, Press Bulletin No. 23. North Carolina Agricultural Experiment Station.

he has killed over 40,000 flies (about four quarts) inside of twenty-four hours in a barn where flies were very numerous.

Other Flies that Carry Diseases

The terrible scourge of Africa known as sleeping sickness is caused by a protozoan parasite known as *Trypanosoma gambiense,* and is transmitted by the bite of a species of fly, *Glossina palpalis.* In our own southern states the disease known as "pink eye" is disseminated by a minute fly of the genus *Hippelates.*



View of an Ill-kept City Stable Yard, showing a manure heap where thousands of house flies breed.

Mosquitoes and Malaria

Malaria has been known ever since 400 B.C. in southern Europe,[13] and from the records it must have been present in Connecticut for about 250 years, though not generally distributed here, nor did it appear in the form of an epidemic until about 1860, when it broke out in the southwestern corner of the state and spread gradually during the next twenty years until the entire area of the state was involved. It is thought that soldiers returning from the Civil War brought it from the south.

The cause of malaria was formerly thought to be gases or foul emanations from swamps, and it was in 1881 that Laveran, a French army surgeon, discovered in the red corpuscles of human blood a protozoan parasite, which he named *Plasmodium malariæ.* Though the mosquito was suggested by King in 1882 as a possible agent in trans-

[13] L. O. Howard, Bureau of Entomology, Bull. 78, p. 37.

mitting this disease, it remained for Dr. Patrick Manson, of London, to point out in 1895 that the malarial parasite had an alternate mode of generation, and he considered some blood-sucking insect (probably a mosquito) as the most probable host. His pupil, Dr. Ronald Ross, an English military surgeon, soon went to India, and after patiently dissecting the bodies of hundreds of mosquitoes, finally discovered one having pigmented bodies in the stomach after biting a malarial patient. In 1900, Sambon and Low, and Grassi, conducted in the most malarious sections of Italy careful experiments which proved to the world that malaria is transmitted to man through the bites of the malarial mosquito, *Anopheles maculipennis.* These experiments have since been duplicated and the results confirmed by many others in different parts of the world.

Mosquitoes breed only in water, and the malarial mosquito will breed in almost any pool where other kinds flourish, but is never so abundant as the rain-barrel mosquito, *Culex pipiens,* or the salt-marsh mosquito, *Culex sollicitans.* It lays its eggs singly on the surface of the water. They hatch in a few hours, and the young larvæ or wigglers feed in the water on minute particles of vegetable matter. Each larva goes to the surface every few minutes to inhale air through the tube or siphon near the tail. In a few days the wiggler changes to a peculiar hunchback pupa, and the adult mosquito emerges two or three days later. Only a week is required in warm weather to complete the life cycle.

As a rule, mosquitoes do not fly far, and usually breed in the vicinity where they occur. The salt marsh mosquito is an exception to this rule, and often flies inland for twenty-five or thirty miles, though it breeds only near the coast.

From the records of the State Board of Health it appears that for the decade ending with 1903, 1,073 deaths, or more than 100 each year, occurred in Connecticut from malarial diseases alone. Dr. Howard obtained similar figures from those states where statistics are kept (less than one half of the states keeping them, and these being in the north), which show that more than 12,000 deaths occurred in eight years from malaria. From the records of a number of cities it appears that two deaths occur from malaria in the south to one in the north, and on this basis and including the non-registration states, he concludes that the annual death rate from malaria in the United States must amount to 12,000, and that it would be 96,000 for the eight-year period.[14]

But with malaria perhaps more than with any other disease the death rate is a small indication of the economic loss suffered. Many

[14] L. O. Howard, "Economic Loss to the People of the United States through Insects that Carry Disease." Bureau Entomology, Bull. 78, p. 10.

are ill for years from malaria, and their capacity for work greatly reduced, and they may finally die from some other trouble.

Yellow Fever and Mosquitoes

As early as 1881, Dr. Charles Finlay, of Habana, noticed a correspondence between the abundance of mosquitoes and the prevalence of yellow fever, but it was not until 1900, when our soldiers occupied the island of Cuba at the time of the Spanish War, that experiments were conducted proving that the disease is transmitted chiefly if not wholly by a mosquito, *Stegomyia calopus*. The investigating committee was appointed by Surgeon General Sternberg, and consisted of Messrs. Reed, Lazear, Carroll and Agramonte.

A small house was built and effectually screened against the entrance of all mosquitoes. A circulation of air was also prevented and all sunlight excluded. A temperature of 76.20° F., with a moist air, was maintained for sixty-three days—just the conditions favorable to the spread of bacterial diseases. Moreover, clothes, blankets and bedding which had been used by yellow fever patients and not cleaned were put into the building and used by the inmates. Seven non-immunes were kept in this house, two or three sleeping in one room with the contaminated bed-clothing, for about twenty nights, then shifts were made and other subjects placed under the same conditions. All seven were released from quarantine in excellent health at the end of sixty-three days, not a single case of yellow fever appearing. Formerly, contaminated clothing, bedding, etc., were regarded as a dangerous source of infection and were usually burned.

Another similar building was erected by these investigators and was divided into two large rooms, one admitting air and sunlight freely and containing the mosquitoes which had previously bitten yellow fever patients. In this room six out of seven persons bitten came down with yellow fever. From the other room mosquitoes were excluded, and the occupants remained in perfect health. These tests still more strongly confirmed previous experiments implicating the mosquito in transmitting yellow fever, and acting on this knowledge General Wood issued orders requiring the use of mosquito bars at the barracks and for the destruction of mosquito larvæ in the breeding pools by the use of petroleum. This work, in charge of Colonel Gorgas, was carried out thoroughly, and continued until Habana was a comparatively healthy city. Mosquito extermination has everywhere been practised—fumigating buildings with tobacco or sulphur to kill the adults, and draining and filling the pools or applying oil to kill the larvæ or wigglers. Of 26,000 of these mosquito breeding places within the city limits in March, 1901, only 300 remained in January, 1902.[15] More-

[15] W. C. Gorgas, "A Few General Directions with Regard to Destroying Mosquitoes." Government Printing Office, Washington, D. C., 1904.

over, the number of deaths from malaria in Habana was greatly reduced from 325 in 1900 to 151 in 1901, 77 in 1902, and 45 up to the first of November, 1903.

In 1905, yellow fever broke out in New Orleans. The situation was critical, and on August 12 was placed under the control of the Public Health and Marine-Hospital Service under Dr. White. A warfare against the yellow-fever mosquito was at once commenced. This mosquito was found breeding in the rain-water cisterns which abounded in the city. These cisterns were screened, and various pools treated. The epidemic abated at once, and the total number of deaths was 460 as against 4,046 in the epidemic of 1878, 4,858 in 1858, and 7,848 in 1853.

Similar control measures have been inaugurated in the Panama Canal zone, with the result that the canal is soon to be completed and the region is now considered fairly salubrious, though the French had to abandon their work there on account of the unhealthy climate.

Measures for Controlling Mosquitoes

Mosquito prophylaxis is usually an engineering problem pure and simple—abolish breeding places. This can be done in nine out of ten cases by filling and draining at small expense. In the tenth case it may be advisable, on account of expense, to make a permanent pool and stock it with carnivorous fishes. The edges should be deep and abrupt, and kept clean and free from vegetation. In the salt marshes, ditches should be opened so that the tide may ebb and flow through them, and mosquitoes will not breed there. Fill all small depressions.

Screen all houses, and also screen all cisterns and rain-water barrels to keep mosquitoes out of them. Treat the surface of all breeding places once each ten days with oil to prevent the breeding of mosquitoes therein until these pools can be made permanently safe.

Fleas and Plague

Bubonic plague, or "black death," has always been one of the most dreaded diseases of mankind, and from the scourge of Egypt, beginning about A.D. 542 and lasting sixty years, down to the San Francisco epidemic of 1907–08, communities and government authorities have been powerless to cope with it. In India even at present, according to the newspapers, the mortality from this disease was 43,508 for the month of February and 95,884 for March, 1911. As it has always been serious in India, various commissions there and in other countries have each investigated and made their own contributions toward a knowledge of the disease. From 1896 to 1903, during these investigations, it was learned that the bacterial germ *Bacillus pestis,* causing the disease, entered through some wound, puncture or abrasion of the skin, and that all fleas and bugs sucking the blood of dying plague-diseased ani-

mals contained plague microbes. Fleas attacking rats were then suspected, and experiments proved that they were capable of transmitting the disease to human beings. Rats and ground squirrels die in large numbers from the plague,[16] which is said to be primarily a disease of rats.

So, working in the light of the knowledge previously gained, Dr. Blue, of the Public Health and Marine Hospital Service, in charge of the outbreak of plague in San Francisco in 1907, directed the warfare against rats, killing more than a million in the city, and disinfecting them as soon as they could be caught. At first the work was difficult. Cases of plague were kept secret. The prejudices of ignorance and superstition had to be overcome. City officials as well as the people had to be educated, and laws made and enforced. But the work was finally performed so thoroughly that San Francisco made a new record in sanitation, and only about 140 cases developed. Except for this effective campaign not only San Francisco and California were endangered, but the whole country imperiled.[17]

Remedial Measures

Destroy all rats by the use of baited traps and poisons, dipping them immediately in a solution of corrosive sublimate to disinfect them. This immediately kills the rats and the fleas, with the plague germs on them.

Fumigate buildings to kill fleas and disease germs.

Build solid concrete foundations, floors and walls where possible in buildings and wharves to keep out rats.

Other Diseases that are Known or Thought to be Transmitted by Insects

There are certain other diseases, mostly tropical, that are known to be carried by insects, and still others that are believed to be similarly transmitted, though the connecting evidence forming the proof is not yet complete. Elephantiasis is caused by worm-like parasites transmitted through the bites of certain mosquitoes of the genus *Culex* in the East and West Indies. Dengue fever and malta fever are probably disseminated by mosquitoes.

It is thought that the germs of leprosy are transmitted by the bites of mosquitoes, flies, fleas, lice, mites or bedbugs. Dr. Patton, of the Indian Medical Service, has demonstrated that the fatal and infectious tropical disease called "kala-azar" is transmitted by the bites of the

[16] R. W. Doane, "Insects and Disease," p. 155.

[17] Report of Citizens' Health Committee, "Eradicating Plague in San Francisco."

[18] R. W. Doane, "Insects and Disease," p. 173.

Indian bedbug, *Cimex rotundatus*.[18] Our bedbug, *Cimex lectularius*, which has always been in disrepute, though constantly appearing in the best society, is now under suspicion. It is not only possible, but quite probable, that in the near future further discoveries will show that some other infectious diseases, like infantile paralysis, and possibly smallpox and scarlet fever, may be transmitted through the bites of some of the common insect parasites of man.

Pestilences were formerly considered as visitations of Providence to punish man for his wickedness. People were powerless to save their own lives or the lives of their friends. Ignorance and superstition are hard to overcome, but in the light of our present knowledge these scourges which I have mentioned are all preventable by controlling the little insects which carry the germs. Is it not therefore a crime to allow them to be repeated?

If the exact history of the world could be written and the truth revealed, it would be interesting to learn whether the decline of Greece was due largely to malaria, as Dr. Ross has suggested,[19] and also to find out how important a part these seemingly insignificant insects have played in shaping the destinies of the nations.

[19] L. O. Howard, Bureau of Entomology, Bull. 78, p. 36.

HOLES IN THE AIR

By W. J. HUMPHREYS, Ph.D.

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THE bucking and balking, the rearing, plunging and other evidences of the mulish nature of the modern Pegasus soon inspired aerial jockeys to invent picturesque terms descriptive of their steeds and of the conditions under which their laurels were won or lost. One of the best of these expressions, one that is very generally used and seems to be a permanent acquisition, is "holes in the air." There are, of course, no holes in the ordinary sense of the term in the atmosphere—no vacuous regions—but the phrase "holes in the air" is brief and elegantly expressive of the fact that occasionally at various places in the atmosphere there are conditions which, so far as flying is concerned, are mighty like unto holes. Such conditions are indeed real, and it is the purpose of this paper to point out what some of them are, when and where they are most likely to occur and how best to avoid them.

Suppose for a moment that there was a big hole in the atmosphere, a place devoid of air and of all pressure. The surrounding air would rush in to fill this space with the velocity pertaining to free particles of the atmosphere at the prevailing temperature; that is to say, at the

velocity of sound in air at the same temperature, and therefore, at ordinary temperature, of about 1,100 feet per second, or 750 miles per hour. Even then, if such a hole existed, it would be impossible for an aeronaut to get into it—he couldn't catch up with it.

But, according to the claims of some, if there are no complete holes in the atmosphere there are, at any rate, places where the density is much less than that of the surrounding air; so much less indeed that when an aeroplane runs into one of them it drops quite as though it was in a place devoid of all air and without support of any kind.

This too, like the actual hole, is a pure fiction that has no support in barometrical records. Indeed, such a condition, as every scientific man knows, could be established and maintained only by a gyration or whirl of the atmosphere, such that the "centrifugal force" would be sufficient to equal the difference in pressure, at the same level, between the regions of high and low density.

Appropriate equations can be written to express the balance between pressure gradient and centrifugal force in any sort of winds, and at any part of the world (it depends slightly upon latitude). Therefore it is possible with certain conditions given to compute the wind velocity, or with other conditions given to compute the pressure gradient. But in the present case numerical calculations are not necessary. We know that an elevation of half a mile, easily reached by any aeroplane, produces roughly a 10 per cent. decrease in pressure; and we know too that a greater pressure difference than this seldom exists even between center and circumference of violent tornadoes. Hence a drop in density, or pressure, to which the density is directly proportional, sufficient to cause an aeroplane to fall, would require a tornadic whirl of the most destructive violence. Now there were no whirlwinds of importance in the air, certainly none that could be called tornadoes, at the times and places where aeronauts have reported holes, and therefore even half holes, in the sense of places sufficiently vacuous to cause a fall, must also be discarded as unreal, if not impossible.

Along with these two impossibles, the hole and the half hole, the vacuum and the half vacuum, should be consigned to oblivion that other picturesque fiction,—the "pocket of noxious gas." Probably no other gases, certainly very few, have, at ordinary temperatures and pressures, the same density as atmospheric air. Therefore a pocket of foreign gas in the atmosphere would almost certainly either bob up like a balloon, or sink like a stone in water; it could not float in mid air. It is possible, of course, as will be discussed a little later, to run into columns of rising air that may contain objectionable gases and odors, but these columns are quite different from anything likely to be suggested by the expression, "pockets of gas."

The above are some of the things that fortunately, alike for those

who walk the earth and those who fly the air, do not exist. We will now consider some of the things that do exist and produce effects such as actual holes and half holes would produce—sudden drops, and occasional disastrous falls.

Aerial Fountains

A mass of air rises or falls according as its density is less or greater respectively than that of the surrounding atmosphere, just as, and for the same reason that a cork bobs up in water and a stone goes down. Hence warm and therefore expanded and light air is buoyed up whenever the surrounding air at the same level is colder; and as the atmosphere is heated mainly through contact with the surface of the earth, which in turn has been heated by sunshine, it follows that these convection currents, or vertical uprushes of the atmosphere, are most numerous during warm clear weather.

The turbulence of some of these rising columns is evident from the numerous rolls and billows of the large cumulus clouds they produce, and it is obvious that the same sort of turbulence, probably on a smaller scale, occurs near the tops of those columns that do not rise to the cloud level. Further, it is quite possible, when the air is exceptionally quiet, for a rising column to be rather sharply separated from the surrounding quiescent atmosphere, as is evident from the closely adhering long columns of smoke occasionally seen to rise from chimneys.

The velocity of ascent of such fountains of air is, at times, surprisingly great. Measurements on pilot balloons, and measurements taken in manned balloons, have shown vertical velocities, both up and down, of as much as 10 feet per second. The soaring of large birds is a further proof of an upward velocity of the same order of magnitude, while the fact that in cumulus clouds water drops and hailstones often are not only temporarily supported, but even carried to higher levels, shows that uprushes of 25 to 30 feet per second not merely may but actually do occur.

There are, then, aerial fountains of considerable vertical velocity whose sides at times and places may be almost as sharply separated from the surrounding air as are the sides of a fountain of water, and it is altogether possible for the swiftest of these to produce effects more or less disconcerting to the aeronaut. The trouble may occur:

1. On grazing the column, with one wing in the rising and the other in the stationary air; a condition that interferes with lateral stability, and produces a sudden shock both on entering the column and on leaving it.

2. On plunging squarely into the column; thus suddenly increasing the angle of attack, the pressure on the wings, and the angle of ascent.

3. On abruptly emerging from the column; thereby causing a

sudden decrease in the angle of attack and also abruptly losing the supporting force of the rising mass of air.

That flying with one wing in the column and the other out must interfere with lateral stability and possibly cause a fall as though a hole had been encountered, is obvious, but the effects of plunging squarely into or out of the column require a little further consideration.

Let an aeroplane that is flying horizontally pass from quiescent air squarely into a rising column. The front of the machine will be lifted, as it enters the column, a little faster than the rear, and the angle of attack, that is to say, the angle at which the wing is inclined to the horizon, will be slightly increased. This, together with the rising air, will rapidly carry the machine to higher levels, which, of itself, is not important. If, however, the angle of attack is so changed by the pilot as to keep the machine, while in the rising column, at a constant level, and if, with this new adjustment, the rising column is abruptly left, a rapid descent must begin—the half hole is met. But even this is not necessarily harmful. Probably the real danger under such circumstances arises from *over adjustments* by the aeronaut in his hasty attempt to correct for the abrupt changes. Such an adjustment might well cause a fall so sudden as strongly to suggest an actual hole in the air.

Rising columns, of the nature just described occur most frequently during clear summer days and over barren ground. Isolated hills, especially short or conical ones, should be avoided during warm still days, for on such occasions their sides are certain to be warmer than the adjacent atmosphere at the same level, and hence to act like so many chimneys in producing updrafts. Rising air columns occur less frequently and are less vigorous over water, and over level green vegetation, than elsewhere. They are also less frequent during the early forenoon than in the hotter portion of the day, and practically absent before sun rise, and at such times as the sky is wholly covered with clouds.

Aerial Cataracts

The aerial cataract is the counterpart of the aerial fountain, and is most likely to occur at the same time. It is seldom rapid, save in connection with thunder storms, and such effect as it may have is exactly similar to, but in the opposite direction from, that of the rising column.

Aerial Cascades

The term "aerial cascade" may, with some propriety, be applied to the wind as it sweeps down the lee side of a hill or mountain. It is most pronounced when the wind is at right angles to the direction of the ridge, and when the mountain is rather high and steep. The swift downward sweep of the air when the wind is strong may carry the aeroplane with it and lead observers, if not the pilot, to fancy that another

hole has been encountered, when of course, there is nothing of the kind. Indeed such cascades should be entirely harmless so long as the aeronaut keeps his machine well above the surface and therefore out of the treacherous eddies, presently to be discussed.

Wind Layers

It is a common thing to see two or more layers of clouds moving in different directions and at different velocities. Judgment of both the actual and the relative velocities of the cloud layers may be badly in error—the lower seems to be moving faster, and the higher slower, than is actually the case. Accurate measurements, however, are possible and have often been made.

These differences in direction and velocity of the winds are not confined to cloud layers, nor even to cloudy weather, as both pilot and manned balloons have often shown. Occasionally balloons float for long intervals with a wind in the basket, showing that the top and the bottom of the balloon are in currents of different velocities. Another evidence of wind layers moving with different velocities is the waves or billows so often seen in a cloud layer. A beautiful example of these cloud waves, both regular, when the directions are the same but the velocities different, and irregular, when the winds are more or less crossed, is shown in the accompanying picture, taken by Professor A. J. Henry, of the U. S. Weather Bureau, and kindly lent for this illustration.

It was explained by Helmholtz as far back as 1889 that layers of air differing in density are of frequent occurrence, and that they glide, sharply divided and with but little intermingling, the one over another in much the same manner that air flows over water, and with the same general wave-producing effect. These air waves are "seen" only when the humidity at the interface is such that the slight difference in temperature between the crests and the troughs is sufficient to keep the one cloud-capped and the other free from condensation. In short, the humidity condition must be just right, and therefore, though such clouds are often seen, air billows must be of far more frequent occurrence.

Consider now the effect on an aeroplane as it passes from one such layer into another. For the sake of illustration let the case be an extreme one. Let the propeller be at rest and the machine be making a straight away glide to earth, and let it suddenly pass into a lower layer of air moving in the same horizontal direction as the machine and with the same velocity. This of course is an extreme case, but it is by no means an impossible one. Instantly on entering the lower layer, under the conditions just described, all dynamical support must cease and with it all power of guidance. A fall, for at least a considerable distance, is absolutely inevitable, and a disastrous one highly probable. To all intents and purposes a hole, a perfect vacuum, has been run into.

The reason for the fall will be understood when it is recalled that, for all ordinary velocities, wind pressure is very nearly proportional to the square of the velocity of the wind with respect to the thing against which it is pressing. Hence, for a given inclination of the wings, the lift on an aeroplane is approximately proportional to the square of the velocity of the machine with reference, *not* to the ground, but to the *air* in which it happens to be at the instant under consideration. If then it glides, with propellers at rest, into air that is moving in the same horizontal direction and with the same velocity it is in exactly the condition it would be if dropped from the top of a monument in still air. It must inevitably fall to ruin, unless indeed rare skill in balancing or, possibly, mere chance should bring about a new glide after additional velocity had been acquired as the result of a considerable fall. Warping of wings, turning of ailerons, dipping and twisting of rudders, and all the other devices of this nature would be utterly useless at first, totally without effect so long as wind and machine have the same velocity, for, as already explained, there would be no pressure on them in any position and consequently nothing that could be done with them would at first have any effect on the behavior of the machine. However, as stated above, a skillful pilot may secure a new glide with a properly constructed machine, and finally, if high enough, make a safe landing.

Of course, such an extreme case must be of rare occurrence, but cases less extreme are met with frequently. On passing into a current where the velocity of the wind is more nearly that of the aeroplane, and in the same direction, more or less of the supporting force is instantly lost, and a corresponding drop or dive inevitable. Ordinarily, however, this is a matter of small consequence, for the new speed necessary to support the machine is soon acquired, especially if the engine is in full operation. Occasionally though the loss in support may be large and occur but a short distance above the ground, and therefore be distinctly dangerous.

If the new wind layer is against and not with the machine an increase instead of a decrease in the sustaining force is the result, and but little occurs beyond a mere change in the horizontal speed of the machine with reference to the ground, and a slowing up of its rate of descent.

Wind sheets, within ordinary flying levels, are most frequent during weather changes, especially as fine weather is giving way to stormy. This then is a time to be on one's guard against the most dangerous of all "holes in the air." It is also well to avoid making great changes in altitude since wind sheets, of whatever intensity, remain roughly parallel to the surface of the earth, and the greater the change in altitude the greater the risk of running into a treacherous "hole." Also,

lest there might be a wind sheet near the surface, and for other good reasons, landings should be made, if possible, squarely in the face of the *surface* wind.

Wind Billows

It was stated above that when one layer of air runs over another of different density billows are set up between them, as illustrated by the cloud picture. Of course, as above explained, the warning clouds are comparatively seldom present, and therefore even the cautious aeronaut may, with no evidence of danger before him, take the very level of the billows themselves, and before getting safely above or below them encounter one or more sudden changes in wind velocity and direction due, in part, to the eddy-like or rolling motion within the billows, with chances in each case of being suddenly deprived of a large part of the requisite sustaining force—of encountering a "hole in the air." There may be perfect safety in either layer, but, unless headed just right, there necessarily is some risk in going from the one to the other, and therefore, since flying at the billow level would necessitate frequent transitions of this dangerous nature, it should be strictly avoided.

Wind Eddies

Eddies and whirls exist in every stream of water, from tiny rills to the great rivers and even the ocean currents, wherever the banks are such as greatly to change the direction of flow and wherever there is a pocket of considerable depth and extent on either side. Similar eddies, but with horizontal instead of vertical axes, occur at the bottoms of streams where they flow over ledges that produce abrupt changes in the levels of the beds.

The inertia of the stream of water, its tendency to keep on in the direction it is actually moving and with unchanged velocity, together with its viscosity, necessitate these whirls with which nearly all are familiar. Similarly, and for the same general reasons, horizontal eddies occur in the atmosphere, and the stronger the wind the more rapid the rotation of the eddy. They are most pronounced on the lee side of cuts, cliffs and steep mountains, but occur also, to a less extent, on the windward side of such places.

The air at the top and bottom of these whirls is moving in diametrically opposite directions, at the top with the wind, at the bottom against it, and since they are close to the earth they may therefore, as explained under "wind layers," be the source of decided danger to aeronauts. There may be danger also at the forward side of the eddy where the downward motion is greatest.

When the wind is blowing strongly landings should not be made, if at all avoidable, on the lee side of and close to steep mountains, hills, bluffs or even large buildings; for these are the favorite haunts, as just

explained, of treacherous "holes in the air." The whirl is best avoided by landing in an open place some distance from bluffs and large obstructions, or, if the obstruction is a hill, on the top of the hill itself. If, however, a landing to one side is necessary and the aeronaut has choice of sides, he should, other things being equal, take the *windward* and not the *lee* side. Finally, if a landing close to the lee side is compulsory he should, if possible, head along the hill, and not toward or from it; along the axis of the eddy and not across it. Such a landing would be safe, unless made in the down draft, since it would keep the machine in winds of nearly constant (zero) velocity with reference to its direction, whatever the side drift, provided the hill was of uniform height and slope and free from irregularities. But as hills seldom fulfill these conditions lee side landings of all kinds should be avoided.

Aerial Torrents

Just as water torrents are due to drainage down steep slopes, so too aerial torrents owe their origin to drainage down steep narrow valleys. Whenever the surface of the earth begins to cool through radiation or otherwise the air in contact with it becomes correspondingly chilled and, because of its increased density, flows away to the lowest level. Hence of clear still nights there is certain to be air drainage down almost any steep valley. When several such valleys run into a common one, like so many tributaries to a river, and especially when the upper reaches contain snow and the whole section is devoid of forest, the aerial river is likely to become torrential in nature along the lower reaches of the drainage channel.

A flying machine attempting to land in the mouth of such a valley after the air drainage is well begun is in danger of going from relatively quiet air into an atmosphere that is moving with considerable velocity—at times amounting almost to a gale. If one must land at such a place he should head up the valley so as to face the wind. If he heads down the valley and therefore runs with the wind he will, on passing into the swift air, lose his support, or much of it, for reasons already explained, and fall as though he had suddenly gotten into an actual "hole in the air."

Aerial Breakers

The term "aerial breakers" is used here in analogy with water breakers as a general name for the rolling, dashing and choppy winds that accompany thunder-storm conditions. They often are of such violence, up, down and sideways in any and every direction that an aeroplane in their grasp is likely to have as uncontrolled and disastrous a landing as would be the case in an actual hole of the worst kind.

Fortunately aerial breakers usually give abundant and noisy warn-

ings, and hence the cautious aeronaut need seldom be, and, as a matter of fact seldom is, caught in so dangerous a situation. However, more than one disaster is attributable to just such winds as these—to aerial breakers.

Classification

The above eight types of atmospheric conditions may conveniently be divided into two groups with respect to the method by which they force an aeroplane to drop.

1. *The Vertical Group.*—All those conditions of the atmosphere, such as aerial fountains, cataracts, cascades, breakers and eddies (forward side), that, in spite of full speed ahead with reference to the *air,* make it difficult or impossible for an aeronaut to maintain his level, belong to a common class and depend for their effect upon a vertical component, up or down, in the motion of the atmosphere itself. Whenever the aeronaut, without change of the angle of attack and with a full wind in his face, finds his machine rapidly sinking, he may be sure that he has run into some sort of a down current. Ordinarily, however, assuming that he is not in the grasp of storm breakers, this condition, bad as it may seem, is of but little danger. The wind can not blow into the ground and therefore any down current, however vigorous, must somewhere become a horizontal current, in which the aeronaut may sail away or land as he chooses.

2. *The Horizontal Group.*—This group includes all those atmospheric conditions—wind layers, billows, eddies (central portion), torrents and the like—that, in spite of full speed ahead with reference to the *ground,* abruptly deprive an aeroplane of a portion at least of its dynamical support. When this loss of support, due to a running of the wind more or less with the machine, is small and the elevation sufficient there is but little danger, but, on the other hand, when the loss is relatively large, especially if near the ground, the chance of a fall is correspondingly great.

Conclusions

1. Holes in the air, in the sense of vacuous regions, do not exist.

2. Conditions in the atmosphere favorable to precipitous falls, such as would happen in holes, do exist, as follows:

a. Vertical Group

1. *Aerial Fountains.*—Uprushes of air, most numerous during warm clear weather and over barren soil, especially above conical hills, are disconcerting and dangerous to the novice, but do not greatly disturb an experienced aviator.

2. *Aerial Cataracts.*—Down rushes of air, like the up rushes with which they are associated in a vertical circulation, though less violent, must also be most frequent during warm weather when the ground is

strongly heated. They too, however annoying to the beginner, should not be dangerous to the experienced man, because even when strong enough to carry the machine down for a distance their descent necessarily becomes slow and their chief velocity horizontal before the surface is reached.

3. *Aerial Cascades.*—Rapid falls of air are found to the lee sides of hills and mountains, and the stronger the wind the more rapid the cascade. But they are of no danger to the aeronaut so long as he takes the precaution to keep above the eddies and other surface disturbances.

4. *Aerial Breakers.*—The choppy, breaker-like winds of thunder storms that surge up and down and in all sorts of directions are as much to be avoided by aerial craft as are ocean breakers by water craft. Hence a flight should positively not be attempted under any such circumstances.

5. *Wind Eddies* (*Forward Side*).—The air on the forward side of a strong eddy has a rapid downward motion and therefore should be avoided. If caught in the down current of an eddy the aeronaut should head lengthwise of the hill or mountain to which the eddy is due. By heading away from the mountain he might, to be sure, get entirely out of the whirl, but the chances are just as great that instead of getting out he would only get the deeper in and encounter downward currents of higher speed.

b. Horizontal Group

1. *Wind Layers.*—The atmosphere is often made up of two or more superimposed layers moving each with its own velocity and direction. Such a condition is a source of danger to the aeronaut because transition from one of these layers to another more nearly coincident in direction and velocity with his aeroplane is certain to result in a sudden decrease in the magnitude of its supporting pressure and in the effectiveness of the balancing devices. Under certain extreme conditions this transition is well nigh inevitably disastrous.

Dangerous wind layers are most frequent at flying levels during the transition of fair to foul weather.

2. *Wind Billows.*—Wind waves analogous to water waves are set up at the interface between two layers that are moving with different velocities. If both layers are moving in the same direction the resulting waves are long and regular; if in different directions they are short and choppy. Therefore, other things being equal, it obviously is advisable to keep within the lower layer, or at least to get away from the billowy interface, either above or below, and to avoid crossing it oftener than is absolutely necessary.

3. *Wind Eddies* (*Central Portion*).—Eddies or horizontal rolls in the atmosphere are found on both the windward and lee sides, especially the latter, of cliffs and steep hills and mountains. When the

wind is strong a landing should not be attempted in any such place. If forced to land in a place of this kind the machine should be headed along and not at right angles to the direction of the hill.

4. *Aerial Torrents.*—Steep barren valleys, especially of clear still nights and when the upper reaches are snow covered, are the beds of aerial drainage rivers that at times amount to veritable torrents. Therefore however quiet the upper atmosphere and however smooth its sailing, it would be extremely dangerous to attempt to land an aeroplane at such a place and such a time.

Note

All the above sources of danger, whether near the surface like the breakers, the torrents and the eddies, or well up like the billows and the wind sheets, are less and less effective as the speed of the aeroplane is increased. But this does not mean that the swiftest machine necessarily is the safest; there are numerous other factors to be considered and the problem of minimum danger, or maximum safety, if the aeronaut insists, can only be solved by a proper combination of theory and practise, of sound reasoning and intelligent experimentation.

THE PHYSIOLOGICAL BASIS OF ESTHETICS

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IN its very etymology the word esthetics denotes perception of sense impressions and implies a physiological reaction between a sense organ and objective stimuli. The significance of the term has become modified to indicate rather the *feelings* produced by the sense perceptions than the mental picture itself. Certain of such are *pleasing* in their effect and the mind inevitably occupies itself in analyzing the factors giving rise to pleasing impressions and attempts to recombine them in relations the results of which will be still more agreeable.

Reason irresistibly seeks to formulate laws which may be used to construct ideals, or concepts of perfect beauty, and we thus have the origin of the fine arts. By general consensus of opinion there is drawn a more or less well defined line of separation between those pleasurable emotions which do and those which do not involve the intellect. The latter are indispensable to the vegetative life, subserving especially the functions of procreation and nutrition.

The former we intuitively apprehend as higher in their nature, leading us to conceptions of perfection, to ideals which lift us above the sordid struggle of selfish existence.

The fundamental query as to the nature and conditions of beauty has engaged the minds of philosophers from the earliest times. Why is one object or group of sensations beautiful, another ugly, another indifferent? "Why we receive pleasure from some forms and colors and not from others," says Professor Ruskin, "is no more to be asked than why we like sugar and dislike wormwood."[1] From Socrates to Herbert Spencer abstract thinkers have devoted their best energies to elucidating the origin and conditions of the Ideals that make up the apotheosis of life.

It would add little to the conception unfolded in the present essay to review the voluminous literature of esthetics; indeed, such a task is far beyond the powers of the writer. A comprehensive synoptical survey of the subject is given by Sully.[2]

The first writer to have attempted to coordinate the development of esthetics with the evolution of physiologic function seems to have been Herbert Spencer.[3] Grant Allen sought to give physiologic basis to the

[1] Quoted by Grant Allen, *infra*.
[2] Article "Æsthetics," *Encycl. Britannica*, 9th Ed.
[3] "Psychology," 2d Ed.

whole esthetic field.[4] Parts of the work of Marshall are especially helpful.[5]

The various conceptions of beauty entertained by any man or race of men strictly conform to the grade of general culture of that individual or that race. Therefore we find the ideals of beauty among different peoples to vary directly with their grade of development in intellect and feeling. Each one of us can trace an evolution of his ideals corresponding with the phases of his mental development.

It would seem, therefore, that an absolute ideal of beauty, whether in morals, in form, in sound or in vision, is not to be found; that the tom-tom of the savage and the violin of the master of symphony are of equal excellence because each expresses most adequately the emotional activity of its respective player.

But psychology remained much like a tractless chaos until students bent themselves to the investigation of laws and functions of the nervous system; and the rich accessions contributed thereby to the knowledge of the mind gives reasonable hope that perception of the beautiful may find in the sense apparatus, which is in general its physical basis, an orderly explanation of facts which otherwise seem without law. If it can be shown that certain esthetic states are dependent for their development upon the specific structure and mode of action of the body in its reaction to external stimuli, it is evidence that the resulting conceptions of beauty are not ephemeral but are founded on the laws of nature which do not operate by chance.

The proof that all esthetic pleasure depends upon a certain harmony between objective stimuli and the structure and operation of the sense apparatus would demand a number of concrete demonstrations correlative with the ideas of beauty.

Nevertheless our main thesis may be firmly founded on a single group of facts if it can be shown that the esthetic attributes of a sense organ arise out of an anatomical or physiological peculiarity of the apparatus which is not concerned in or is even opposed to its prime utilitarian function. Our knowledge of biology appears to be too meager to support a generalization in this field, but certain known facts as to the reactions of the visual apparatus establish that certain of its idiosyncrasies which would condemn it as an optical instrument lend themselves to the development of ideals of visual beauty.

The astonishing revelation appears that when in the evolution of our visual organs under operation of the Law of Usefulness the structure has taken on characters which are inherently subversive of its utilitarian functions, nature has, as it were, circumvented the tendency of these defects; and out of them arise interpretations of the external

[4] "Physiological Æsthetics," 1877.

[5] "Pain, Pleasure and Æsthetics," 1894.

world which lose nothing in exactness but gain something altogether new—esthetic feeling.

Vision is the sense which provides the mind with an overwhelming preponderance of the sensations which lie at the basis of esthetic conceptions. If it can be demonstrated that esthetic visual ideas are founded upon reactions which are dependent upon anatomical peculiarities of the sense organ, the main purpose of this argument will have been accomplished. The evidence follows:

The globe of the eye is admittedly the analogue of a photographic camera, but it is marked by mechanical imperfections that would completely unfit it for the projection of a sharp image upon the sensitive plate. For the eye lets in light not only through the pupil, which corresponds with the aperture in the photographic diaphragm, but the side-wall of the globe—the sclerotic coat and its underlying choroid coat—are penetrable to the light. Consequently, the whole retina must be bathed in a dim light which has entered through the wall of the eye-ball. This light is diffuse, and since it has traversed many blood streams it must have acquired a reddish color.[6]

Under ordinary conditions of vision then, there is thrown upon the center of the retina a more or less sharply defined image of objects the light from which has entered the pupil. In addition, the whole of the retina is illuminated by a diffuse reddish glow, due to light leaking through the white of the eye, a condition the parallel of which would completely subvert the efficiency of an artificial camera. Apparently, then, evolution has produced for us an optical instrument which is hopelessly defective. But the sensitive film of the eye is alive and the impressions formed on it are interpreted through the aid of living structures. It is conceivable that what seem to be mechanical deficiencies in the eye may be compensated or even turned into actual benefits through physiological agency.

It is a familiar law of chromatics that whenever an objective color falls upon the retina, the affected area becomes fatigued for that color and refreshed for its complementary. The complementary color of red is green. Under the conditions named, then, the irritability of the retina for green is continually maintained through the influence of light leaking through the sclerotic coat. So long as this side light penetrates the globe of the eye, and such is the habitual condition in daylight, the perception for green is automatically refreshed and this color, therefore, excels all its companions of the spectrum in its ability to play upon the sensorium without inducing fatigue.

Now the characteristic tint of vegetation is green. A tree clothed with verdure never wearies the color sense. But look at this same tree through an opaque mask having eye-holes admitting light only

[6] Cf. Brücke, *Pogg. Annalen*, Bd. LXXXIV., S. 418.

through the pupils, and very soon the foliage takes on a rusty hue, the esthetic charm of the creation departs and the onlooker feels a sense of depression; all because the sidelight entering the white of the eye has been cut off.[7] Such may be the physical basis of that droop in spirits which every one is apt to feel on a summer's day when a cloud suddenly obscures the sun.

Such is one indication that the universal esthetic joy of the open, as far as dependent on the color sense, is specifically subserved by the physiological reactions of the eye, reactions which would seem to impair the efficiency of the organ as a mere optical apparatus. A mechanical defect is translated by physiological intervention into a psychic triumph.

In the foregoing it has been shown that esthetic feelings may be founded directly upon anatomical and physiological peculiarities of the eye. Now I will proceed in the converse manner and attempt to account for some intuitively perceived esthetic qualities by reference to idiosyncrasies of the visual instrument. It is doubtful whether ideals of beauty can ever be embodied by the conscious mathematical synthesis of their elements as a mechanic constructs a building by laying stone on stone.

I imagine that the creation of the artist at first appears to him as an intuition, of a quality determined by his race culture, and that he uses his techniuqe to put together objective materials to represent it. But such a work is its own justification; it is accepted and graded at its face value by a general consensus of cultured opinion, according as it is fit and pleasing, irrespective of the laws of physics and physiology. If it is beautiful it may claim place as a model of taste, needing no defense. Now if beauty of whatever sort is but the outcome of certain correlations of physiological and anatomical characters, it should be possible to point out the biological substratum on which depends the excellence of any work of art.

But few works of art appeal to all men as approaching objective perfection. Possibly one such structure in architecture is represented by a ruin—the Parthenon at Athens. Many themes have been written in admiring description of this building; much has been debated the secret of its charm. With great diffidence I venture to dwell upon certain reported peculiarities of construction of the Parthenon as they appear to me related to known facts of binocular vision, and to suggest that from this interdependence springs at least part of the esthetic satisfaction aroused by the structure.

Competent observers describe one physical detail in the construction of the Parthenon which has aroused much curious comment.

[7] Sewall, "On the Physiological Effects of Light which Enters the Eye through the Sclerotic Coat," *Journ. of Physiology*, 1883, V., p. 132.

> No line and no form in the composition of the temple are exactly what they appear to be: . . . No horizontal line is really horizontal, and no vertical line really vertical, . . . every huge and massive feature is changed and almost imperceptibly deflected from the appearance it bears.[8]

The free edges, namely, of the edifice instead of being straight, as in a modern architectural design, are all curved gently in the arcs of large circles. The edges and vertical faces of the steps leading to the portico thus have a gentle convexity outward. The surface of the platform itself has the form of a very flat vault. The columns do not stand exactly vertical, but slant inward and their outlines are curved so that their actual thickness is greatest about one third the distance from the base. So great is the radius of curvature that to the casual glance there is no departure from straightness in the outlines.

Such being the objective mechanical facts, let us see what relation they may have to the visual physiology of the onlooker.

The physiological conditions may be made clear by means of a simple experiment. Let a cross formed of two strips of colored paper which intersect at right angles be fastened against a neutral tinted wall at the level of the eyes of the observer who stands at a distance of, say, ten feet. The gaze is fixed intently for some seconds upon the center of the cross. The image of the latter is thus impressed upon the retina, so that when the glance is directed elsewhere upon the wall a "negative after-image" of the cross is projected with startling distinctness upon the surface. When the eyes move so that the optic axes run along either the horizontal or vertical lines extending from the center of the cross the limbs of the latter maintain their true directions in the after-image. But when the optic axes are directed obliquely upward or downward, the cross seems to be inclined upon the wall, the vertical limb leaning at a greater angle than the horizontal. When the orbital movement is upward and to the right, the vertical part of the cross inclines to the right, it may be as much as fifteen degrees; the horizontal limb inclines downward to the right as much as five degrees.[9] When the oblique movement of the optic axes is upward to the left the inclination of the cross is to the left. Oblique downward movements give complementary results. The amount of angular inclination of the after-image is proportional to the range of oblique movement. The physiological explanation of this phenomenon is not here important; the results are such as would occur if the eyeball in its oblique motions rotated slightly like a wheel about its visual axis.

As an observer stands before an architectural structure, his gaze roving over its lines and surfaces, the extremely complex nerve-muscle

[8] "Greek Art and Modern Craftsmanship," *Edinburgh Review*, October, 1906, Vol. 204, p. 430.

[9] Le Conte, "Sight," p. 164. Internat. Scientific Series, 1881.

mechanism of ocular fixation must carry out its movements with an ease or effort determined by the external configuration brought into attention. It has been shown that in oblique movements of the eyes there is a definite rotatory movement of the globes, so that in following any line departing obliquely from the prime axis of vision it seems obvious that the fixation mechanism would suffer less fatigue when this line is curved objectively to correspond with the normal rotation round the visual axis. In following oblique lines which are objectively straight the fixation mechanism must be continually harrassed by the voluntary effort to maintain the contemplated line in the horopter.

No homily is needed to convince the modern physician of the paramount psychological importance of the motor sensations arising from the coordinations of the external eye muscles. As sensory disasters from eyestrain often result in muscular unbalance, it is not difficult to believe, conversely, that peculiar advantages may spring from unobtrusive objective aids to the action of the intricate machinery of fixation whereby the eye is enabled to rove over a picture without conscious effort. According to this view, then, the curved lines of the Parthenon are psychologically straight to the onlooker in so far as they parallel the normal inclination of the after-image in oblique vision. It is easy to believe that the physiological result of such relations is rest, absence of fatigue. But kind nature repays subconscious physiological coordination in a rich and peculiar way; the thing so seen and understood without effort arouses a new class of ideas—an esthetic feeling—beauty.

It may be objected to the foregoing argument that, though the outline of one side of a column may by reason of its curve allow the eye to glance along it without the effort of fixation, that of the opposite side, forming a reciprocal arc, must simultaneously offer an equally exaggerated impediment to ease of vision. I answer that the percipient mind tends to neglect all sensory impressions which interfere with the homogeneity of a mental picture. The infinite details of a landscape impressed upon the outskirts of the retinæ give rise for the most part to mental double images, but these in no wise disturb the acuteness of vision for an object projected on the retinal foveæ. Moreover, it is not intended here to imply that the idea elaborated above contains the whole physiologic basis of the esthetic charm of the Parthenon. Indeed, the author of the admirable paper[10] which has been quoted, whose thesis, by the way, ascribes the preeminence of Greek art to its foundation on physiological principles, himself gives other interpretations to the psychic impression produced by the temple. These explanations, however, do not displace, but rather complement that detailed above.

In the foregoing discussion evidence has been offered along two

[10] *Edinburgh Review, loc. cit.*

different lines that structural or functional properties of the eye which, considered from the purely physical point of view, would seem to impair the efficiency of the organ as a registrar and transmitter of objective visual facts, not only do not confuse the recipient sensory nerve centers, but, on the contrary, the psychical apprehension of objective phenomena is distinctly modified by the reaction to such instrumental defects in a manner which leads to the generation in consciousness of a state or an atmosphere of feeling—esthetic feeling. It is as if the stone rejected of the builders were made the chief of the corner.

In pursuance of this line of thought I will offer one additional illustration of the direct dependence of psychic perception upon what may be termed the structural aberration of the visual apparatus.

When external objects are viewed with one eye, held at rest, the image upon the retina is exactly similar to that upon the sensitive plate of the camera, it has length and breadth, but no depth, and it has no power of directly arousing in the mind a perception of the third dimension—projection.

It is inconceivable, indeed, that an anatomical apparatus should be capable of directly presenting to its sensory center an impression of depth. Such a perception is of purely psychological construction from simpler data derived from retinal impulses. By an exceedingly familiar line of evidence it can be shown that the direct visual perception of depth is dependent upon idiosyncrasies of binocular vision. It is a physiological law that an object viewed by the two eyes appears to be single only when the images which it casts upon the retinas fall upon "corresponding points" of the two surfaces. It is obviously of paramount importance to the instrumental efficiency of the eyes that there should be a horopter in which objective and subjective facts must coincide. It is well known that the fixation of objects by means of which their images are retained upon corresponding retinal areas invokes activity of most complex nerve-muscle machinery. Now when a small solid object is viewed with both eyes, it is clear that the right eye must see more of the right side of the object and the left eye more of the left side. Therefore it is certain that the images on the two retinas can not be identical and therefore can not exactly "correspond."

Some extra-mundane theorists summing up these facts would naturally reach the conclusion that distinct binocular vision is in its nature impossible. Nevertheless we know that the mental picture of external objects loses nothing essential in focal sharpness through binocular vision but, on the other hand, the two unlike retinal pictures combine, as it were, in the mind to form a new idea—the concept of depth.

Of all esthetic perceptions that of projection is the highest, the most purely psychic. Through it the universe is instantly converted from a

flat surface of two dimensions into an infinity reaching in all directions. If the unlikeness of the retinal images as seen simultaneously with the two eyes is really the physical basis of our visual perception of the third dimension of space it would naturally be suspected that the depth perception must become more lively the greater the unlikeness of the two images, up to a certain point. Manifestly the binocular images must depart from similarity in proportion as the eyes are further apart.

Pursuing this idea, Helmholtz contrived a most ingenious instrument the "telestereoscope," by which the distance between the eyes of an observer can be virtually increased to any extent. In its simplest original form the telestereoscope may be reproduced by joining at right angles the edges of two small squares of silvered glass which are then set into the middle of a strip of board having a length of, say, three feet. When the eyes are brought close to this rectangular mirror so that its edge is parallel with the bridge of the nose, it is evident that the right eye sees only the reflection of objects to the right of the field of view and the left eye those in the corresponding area on the left. At each free extremity of the board another, larger mirror is placed, so fastened by hinges that one mirror shall be movable round a vertical and the other round a horizontal axis. These terminal mirrors have their reflecting surfaces turned outwards, away from the observer.

In using the instrument the experimenter brings his eyes close to the fixed rectangular mirror so that they look into either reflecting surface. Now the terminal mirrors are focused on some distant object, as a tree, and it is easy to bring the reflections of the two images on "corresponding points" of the retinas and the distant object appears single but as if viewed by a pair of eyes separated by a distance of three feet. No one can realize, without having experienced its influence, the startling stereoscopic effect of such a view. For the first time in his experience the observer becomes enthralled with a perception of depth as a specific factor in objective impressions. It seems to the writer worth recording, as a suggestion in esthetic pedagogics, that after continued experimentation with this apparatus for some weeks, during which all manner of solid objects occupying the landscape was studied, there insensibly grew up in him an esthetic appreciation of depth, *per se,* which gave to all solid objects, viewed with the unaided eyes, a charm which immensely enhanced the pleasing combination of their natural attributes. The beauty in nature called more insistently from all her creatures. To sum up, in brief, the very dissimilarity of the retinal images which would seem to subvert the acuity of binocular vision is not only without disadvantage thereto but forms the physical substratum of a new psychic realm.

To the writer these facts and reflections seem very strong evidence that the principles of esthetics, like those of the psychology from which they spring, are fundamentally an outgrowth of physiological and anatomical factors and phenomena. The belief seems to prevail among psychologists that the general states of pleasure and pain are referable to functional nutritive metabolisms of the sensory apparatus which, on the one hand, tend to restore and, on the other, to destroy it.

There is experimental evidence that the emotion of fear and the sensations of pain, at least the sensations resulting from trauma, have a physical basis, manifested by histological alterations in the nerve cells of the brain.[11] It might be plausibly argued that the scheme of usefulness which is the basis of organic evolution accounts for the origin and development of an esthetic sense.

But the peculiar mechanical substratum of the esthetic faculty as far as it is related to the visual apparatus seems to be seated in *idiosyncrasies* of the sense organ which have, at first view, no important relation to its usefulness as a physical instrument; which, on the contrary, would seem to be impediments to the perfection of its main function. This is suggestive of the thought of Herbert Spencer that the distinguishing mark of esthetic sentiments is their separableness from life-serving functions.

Curious it is, and still stranger if a matter of chance, that where the utility of a sense organ ends its glory may begin.

[11] Geo. W. Crile, "Phylogenetic Association in Relation to Certain Medical Problems," Ether Day address, Mass. Genl. Hosp., October 15, 1910.

ARE THE JEWS A "PURE RACE"?

By ABRAM LIPSKY, Ph.D.

NEW YORK CITY

DR. MAURICE FISHBERG has brought together in a book on "The Jews"[1] a great mass of valuable anthropological and sociological statistics. The work is likely to become a standard reference handbook for some time to come. For that reason it is deplorable that the author should have marred its value by over-zealousness in supporting a thesis that did not actually lie within the scope of his undertaking. He believes that the Jews are destined to be assimilated by the races among whom they live in Europe and America, and it is apparently in order to facilitate this manifest destiny that he arrays all the arguments he can muster tending to show that the Jews are not a pure race.

There are certain physical traits generally assumed by anthropologists to be distinctive of race. Dr. Fishberg finds that in these respects the Jews are not different from the races amongst whom they live. Certain other characteristics of a moral, social and vital or physiological nature, often ascribed to the Jews, are either denied existence or attributed by the author to economic and social status rather than to race.

The chief physical characteristics relied upon to distinguish races are stature, head-form and color. As to stature, Dr. Fishberg shows that the Jews rise and fall with the people in the land of their nativity, being short where the gentiles are short, and tall where they are tall, though never quite as tall. That stature is influenced by environment, is conceded by Dr. Fishberg—his own measurements on Jews in New York and those of Dr. Jacobs on the Jews in London leave no doubt on this point. A little of the Jewish variability in stature is reserved, nevertheless, to be ascribed to racial intermixture.

As to head-form Dr. Fishberg is more decided. The heads of European, Caucasian, African and Arabian Jews vary in shape. Some are long, some are broad, some are round. Only the commingling of the blood of different races could have produced these differences, argues the author.

Now, strange to say, in eastern Europe—in Russia, Poland, Hungary, Roumania—the Jews have remarkably uniform heads. These Jews

[1] "The Jews, a Study in Race and Environment," by Maurice Fishberg, M.D., Contemporary Science Series, Charles Scribner's Sons, New York, 1911.

constitute eighty per cent. of all the Jews in the world. Does this uniformity indicate unity of race? Not at all, according to Dr. Fishberg. The gentiles in these regions, who, we know, are of different races, also have remarkably uniform heads. It follows that the Jews acquired their uniformity of head-shape by fusion with their non-Jewish neighbors. That is to say: When Jewish heads are various in shape, it proves that the blood of various races flows in their veins, and when their heads do not vary much in shape, the same thing is proved. On one page Dr. Fishberg writes as if head-form were an unchangeable racial characteristic—on that page, since the heads of Jews in Europe, Africa, and Asia vary—the Jews are not a race. On another page, the Jews are not a race for the opposite reason, namely, because eighty per cent. of them have heads of the same shape—since it happens that the many gentile races living in the same part of the world also have similar heads!

Dr. Fishberg introduces his table showing how much alike are the heads of the Jews in eastern Europe with a remark from Professor Ripley's "Races of Europe." "The perfect monotony and uniformity of environment of the Russian people," says Ripley, "is most clearly expressed anthropologically in their head-form." If the environment is clearly expressed in the head-form of the gentiles, why is it not also expressed in the head-form of the Jews? The Jews have lived in that environment for the last ten centuries, at least. Would Dr. Fishberg suggest that Jewish heads alone are impervious to environmental influence? That environment has an effect upon head-form has been confirmed by the recently published measurements of Professor Boas on 30,000 immigrants and their descendants. These measurements show that, "The head-form undergoes far-reaching changes due to the transfer of the races of Europe to American soil. The east European Hebrew, who has a very round head, becomes more long-headed; the south Italian, who in Italy has an exceedingly long head, becomes more short-headed; so that both approach a uniform type in this country so far as roundness of the head is concerned . . . we are compelled to conclude that when these features of the body change, the whole bodily and mental make-up of the immigrants may change." Environment, it thus appears, may act directly upon Jewish heads as well as upon Russian or Italian.

Head-form has been regarded by anthropologists as the most stable of racial characteristics. If that, together with "the whole bodily and mental make-up of immigrants, may change," one need hardly be surprised to find that color of eye and hair too are modifiable by environment. Dr. Fishberg does not, however, allow such a possibility to disturb the serene course of his argument. You may mix colors by intermarriage of races, but nothing else can affect their everlasting fixedness.

The usual assumption is that the Jews, originally, if they were anything, were brunettes. But Dr. Fishberg finds that hardly more than half—52 per cent. of the males, and 57 per cent. of the females—are dark. The blonds, he concludes, must be due to past intermarriages with non-Jewish races.

Is the conclusion inevitable? Animals are known to change color with a change of environment—why not men? Professor Ridgeway in his presidential address to the Royal Anthropological Institute, January, 1910, refers to a bit of positive evidence that they may. Mr. J. V. Hodgson, biologist of the Scott Antarctic Expedition, reported that as a result of living under such unusual conditions, the eyes of the members of the expedition became so blue as to occasion remark on their return to New Zealand and also on their arrival home in England. "Color, therefore, like the cephalic index and stature, is also prone to change and in itself is not deserving of implicit trust."

Dr. Fishberg dilates upon the statistics of intermarriage between Jews and Christians in Europe to support his thesis that assimilation is the destiny of the Jews, as mixture has been their history. The figures for certain localities are sufficiently striking. In Prussia, during 1900–1907, there were 21 mixed to every 100 pure marriages. In Berlin there were, in 1905–6, 44 mixed marriages to every 100 pure Jewish marriages. In Hamburg and Copenhagen similar high rates of intermarriage are found. Dr. Fishberg argues that the Jews are bound to become even more composite as a race than they are now.

His zeal, however, seems to get the better of him. He points out that this intermarrying tendency means an appreciable loss to Judaism, and the more so since the children of mixed marriages tend to marry with Christians rather than with Jews. The children of mixed marriages are mostly brought up in the religion of the non-Jewish parent. "It is Ruppin's opinion that hardly ten per cent. of the children resulting from mixed marriages remain Jews for any considerable length of time. Of these it is doubtful whether any Jews are left after two or three generations." But a couple of pages farther on we are impressively reminded of the "new anthropological types" that are being introduced "among the children of Israel." We ask: If none of the offspring of mixed marriages are left among the Jews after two or three generations how can new anthropological types arise among them? And we ask further, whether the anthropological types that Dr. Fishberg finds now among the Jews arose in the same way!

He quotes Professor Boas's statement that if two types of equal number intermingle, there will be in the fourth generation less than one person in ten thousand of pure blood; and if one group is smaller than the other, it will, of course, lose its identity even more quickly. But Professor Boas assumes, in order to be able to make his calculation, that

the intermingling proceeds by chance, that there are neither artificial accelerations nor restrictions. Admit, however, that the mingling does not go on by chance, that there is a much more powerful tendency for kind to mate with kind than for intermarriage, and admit, further, that all the children of mixed marriages are drained off into one of the groups, leaving after the second or third generation none in the other, and you have a totally different result. Your smaller group, from which the offspring of intermarriage are drained off into the larger, will remain pure for ages, and a more interesting problem than of the purity of the smaller group arises, viz., the extent to which its constant losses have leavened the larger group.

It has been suggested by Professor Ripley that the Jewish type, if not due to racial continuity, may be due to choice, or, in other words, to sexual selection. Others have pointed out that in the principle of sexual selection we have an explanation for the resemblance between the Jews and the gentiles in every country where they live together. The gentile type being the dominant one, it becomes a distinction and a social advantage for a Jew to be of the gentile type. The gentile type of manhood and of beauty, commonly bolder, freer and happier than the Jewish, excites the admiration and envy of the victims of oppression. Hence, the gentile features are prized, selected and preserved. Dr. Fishberg agrees with Professor Ripley as to the effectiveness of sexual selection, but he denies that the gentile type would be the one selected. He contends that the Ghetto Jew abhors the gentile type. On this point we have only his own unsupported opinion. When it suits his purpose, Dr. Fishberg sees nothing but the Ghetto. He seems to forget the very considerable periods of comparative freedom the Jews have enjoyed in Europe. And what becomes of his thesis at this point? How could the intermarriages that he is so sure have taken place if there had always existed an abhorrence for the gentile type?

Dr. Fishberg finds nothing racially distinctive in any of the commonly alleged vital, social or moral characteristics of the Jews. Their great "tenacity of life" has often been spoken of. Statistics from the United States Census confirm the opinion as to their lower mortality. In the census for 1900 it is shown that their death rate is astonishingly below that of other people living under the same conditions. In three of the most crowded wards of New York city the mortality of the Jews was 17 per thousand; whereas the mortality of the Germans living under the same conditions was 22, of the Irish 36, and of the native Americans 45. Dr. Fishberg remarks upon this phenomenon that what we have here is not a racial characteristic. The low death rate of the Jews is not due to "tenacity of life"; in fact, adult Jews die as soon as other adults. The figures of the census merely indicate the fact of a low infant mortality, and this is due not to any racial peculiarity but to the

great care and watchfulness of Jewish mothers. There he leaves the matter. One naturally inquires why the Jewish mothers in those congested wards display a solicitude for their babes so much greater than other mothers in the same district, that half as many Jewish infants die as Irish, and two and a half times as many children of native Americans die as of Jewish! It will not do to say, as Dr. Fishberg does in one place, that fewer Jewish mothers work away from home. That is only putting the same fact in another way. Why do they not go away from home? They are just as poor as the Germans, Irish and native Americans in those wards. If a phenomenon of this sort were observed, say, among birds—such a greater affectionateness on the part of one set of mother-birds than on the part of another set, with such an astonishing difference in infant mortality—the ornithologist would unquestionably be strongly inclined to think he was dealing with different species of birds. Dr. Fishberg is studying types of humanity, whose evolution and differentiation are more along mental, moral and social lines than along physical lines; but when he comes to a phenomenon that is of a spiritual character he passes it by as a matter of small significance.

One would think that since Dr. Fishberg is so averse to attributing any of the observed peculiarities of the Jews to race, he would look for their causes in moral and religious habits that are distinctively Jewish; for if the Jews are not a race in the physical sense, they must be a religious community. But Dr. Fishberg's aversion to doing the one thing seems to be as great as his aversion to doing the other. He admits, for example, that the Jews all over the world show a remarkable freedom from alcoholism. "Many physicians state that in their professional experience they have never treated one for inebriety." Drunkards are rare among them. To what is this sobriety due? Neither to race, nor to religious or moral training, according to Dr. Fishberg, but simply to their life in Ghettos, which cut them off from the ways of the gentiles and gave them an abhorrence for their customs. The proof is that as soon as they emerge from the Ghettos inebriety increases among them. Here again we have only the author's unsupported statement as to a matter of fact.

The Jews are credited with immunity from certain diseases and greater susceptibility to others. Dr. Fishberg admits their surprising immunity from tuberculosis. Even when living in the most crowded and unsanitary quarters, their mortality from this disease is far below that of other people. What is the cause of this comparative immunity? Some say it is race; others, that it is their dietary scrupulousness. It is neither, says Dr. Fishberg. Their immunity is partly due to their freedom from alcoholism; partly to their long experience in urban life which has cut off those too weak to withstand the disease, leaving only

the comparatively immune. That dietary scrupulousness has had nothing to do with lowering the mortality from tuberculosis, argues Dr. Fishberg, is proved by the fact that the Jews in Harlem, who have become more indifferent to dietary regulations, are less susceptible to the disease than the Jews on the East Side. Here we have a very palpable example of Dr. Fishberg's special pleading and his effort to support his thesis even at the expense of consistency. If it be true, as he says, that Jews become more addicted to alcoholism as they emerge from the Ghetto, and if alcoholism is one of the chief causes of susceptibility to tuberculosis, then why are not the Jews of Harlem, emancipated from the Ghetto and more alcoholic as they are, according to the author, more rather than less susceptible to tuberculosis than the Jews on the East Side?

When no other explanation than race, or habits governed by religious or moral ideas, occurs to him, Dr. Fishberg prefers to plead ignorance rather than admit the effectiveness of these causes. He grudgingly confirms, for example, the comparative immunity of Jews from cancer. The striking exemption of Jewish women, especially, from cancer of the uterus has been confirmed by many physicians and Dr. Fishberg also affirms it. As usual, race and diet have been offered as explanations. Dr. Fishberg refrains from presenting a counter explanation because of the meagerness of our knowledge of the nature of cancer, but dismisses without another word the explanations that have been suggested.

If ever one would be justified in looking to religious and moral peculiarities for causes, it would surely be when dealing with statistics of crime. The Jews, Dr. Fishberg argues, are not a racial unit. They are some sort of a unit, or Dr. Fishberg's book would be without a subject and without a title. Call them a religious community, then, although scattered over the whole world. It is hardly necessary to dwell upon the close relationship between Jewish religion and Jewish morals. The Ten Commandments, the preaching of the Prophets, the minute legislation of the Talmud, all are aimed at regulating conduct. Can we assume that the Jews have remained a religious community for so many centuries, bound together by loyalty to these moral maxims, incessantly rehearsing and teaching them, without an appreciable effect upon actual practise? Dr. Fishberg's position implies that we must make this assumption. The statistics of Jewish criminality in those countries where they have been kept are remarkable. In Hungary, for instance, in 1904, there was 10.5 times as much manslaughter, 9 times as much robbery, 7 times as much homicide, 6.3 times as much assault, 4.23 times as much arson, in proportion to their numbers by Christians as by Jews. Similar statistics are available from several other countries. On the other hand, more Jews than Christians were convicted of bankruptcy, duelling, usury, fraud, perjury and forgery.

Dr. Fishberg concludes that there is nothing racial, moral or religious about this phenomenon. It is all explained by the Ghetto and by the nature of the occupations in which the Jews are engaged. Their freedom from crimes of violence is due to their weakness and cowardice; their proneness to mercantile crimes is due to their rapacity in business. As they emerge from the Ghetto and become physically more robust, crimes of violence too increase among them. That the terrible struggle for existence in the restricted areas to which they are confined in Europe is the cause of much transgression against the laws of property is probable; but weakness and cowardice explain nothing. The weakest and most cowardly are often the most quarrelsome and the most cruel among themselves. Jackals fear the lion, but they have no fear of one another. Dr. Fishberg has written a book about the Jews, as a people who are not a race or a nation, in his opinion, but scattered communities unified by religion, yet their religion has had no effect upon their lives, and its only outcome has been the Ghettos that Christians have forced them to live in!

As one proceeds through the multitude of figures, assertions and arguments in Dr. Fishberg's book, one becomes doubtful as to what he is really driving at. It would seem, offhand, that he wished to convince us of the fact that the people now called Jews are not descendants of the same original stock. "Ethnologically," he says, "there are practically no differences between Jews and other Europeans. Both consist of conglomerations of various racial elements blended together in a manner that makes it impossible to disentangle the components, or even the predominant race out of the ethnic chaos." But if his aim was to prove this, what was the use of wasting so much zeal and labor? On page 135 we are told, "One thing is certain, however, the original stock of the Jews was not made up of a single and homogeneous race, as is supposed by some." And again on the same page we read that the Bible itself records inter-marriages between Jews and gentiles and "that some of these races were not of Semitic stock has been established recently by archeological research." Why was it necessary to produce more evidence; why worry about blonds and long heads and short heads, if the Jews never were Jews?

But why should we be concerned whether the Jews are, or ever were, a "pure race"? What is a pure race? Would Dr. Fishberg know one if he saw one? If there ever was a pure race how did it come into existence? Was it born pure, or did it issue pure from the Hand of God? "Religion," says Dr. Fishberg, "the Jewish as well as the Christian and Mohammedan, with the assistance of the state, artificially created the types of the Jew at the beginning of the nineteenth century. There is nothing unusual that an isolated community should evolve peculiar characters." Does Dr. Fishberg know any other way

than isolation by which races acquire peculiar characters? The Jews of remote antiquity seem to have had characters sufficiently peculiar to cause themselves to be known as Jews. How did they get those characters? Was any thing but isolation ever the cause of such peculiarities? How did the American Indians, the Anglo-Saxons, the Ethiopians get their peculiar characters? Does Dr. Fishberg imagine they inherited them in an uninterrupted line of descent from a primordial group or pair that had them since first there were men on earth?

It could easily be shown that there is as much diversity of religion among the modern Jews as of physical type. If we followed Dr. Fishberg's method we could prove that the Jews are neither a race nor a religious community. And yet what have historians been talking about when they have written about the Jews? To what have the Jews, if we may still use the term, been loyal all these centuries? And to what shall be ascribed that Hebraic influence of which writers as diverse as Matthew Arnold and Nietzsche speak with confident appreciation or reprobation?

Dr. Fishberg seems to think that in presenting evidence tending to show that the Jews are not a pure race, he has provided the most deadly possible reply against those who dream of reconstituting the Jews as a nation. If the Jews are not a race, if all their peculiarities vanish as soon as you change their economic status, then it is folly with such material to undertake any work of reconstruction. The Jews are an evanescent phenomenon, and we shall be wise if we gracefully acquiesce in their disappearance. As if men interested in the welfare of their kind ever troubled themselves about such metaphysical entities as Dr. Fishberg's "pure race"! His contention that the Jews are not a pure race has no point. It makes no difference whether they are or not, since the only so-called pure races are a few small groups like the Basques and the Esquimaux, which, through long isolation, have attained a high degree of homogeneity—at least to European eyes. "Pure races" are anthropological postulates, like the atoms of physicists, which serve a scientific purpose but never can be brought in to decide practical questions of politics or engineering. Dr. Fishberg tries to use the conception of a "pure race" in such an illegitimate manner. In his eagerness he falls repeatedly, as we have seen, into inconsistencies unbecoming, to say the least, in a scientific work. After a candid perusal of it, one has to declare in true Irish fashion that the arguments do not prove that the Jews are not a pure race, and even if they did, it would make no practical difference to any one or any thing.

IS A SCIENTIFIC EXPLANATION OF LIFE POSSIBLE?

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THE restoration of this question in recent times to a position of some apparent respectability among the biological problems of the day is a striking example, not only of the vitality of misconceptions, but also of the vanity of men. Of course, we do not know all about life, or anything else, and probably never shall, but the outcome of this confession bears no resemblance whatever to the hopeless figure of a future, discounted, and forever condemned to total silence. To refuse the men of to-morrow the chance to explain what they can, may produce in some minds a pleasing artistic, or even philosophic effect, but no one can cut short the road to truth, or travel thither on his own terms, for the conditions under which nature transports us are rigid, unfavorable, and as plain as the rules printed on a railroad ticket. Nor is the rate low, for she demands not only money and unlimited patience, but all of our fondest prejudices, and our most natural and ingrained faults as well, must be left at the station window, before we depart. Nature gives passage only to modest folk who do not pretend to know everything before they start, and who are ready to give up the past, and let bygones be bygones.

If I were to ask for a scientific explanation of rain, I should be told that at a given temperature and barometric pressure, the air dissolves a limited amount of water vapor which evaporates chiefly from the surface of the ocean, and rises in the sky. When cooled, as it often is at high levels, or by chilling winds, the vapor condenses, and if the cooling proceeds beyond a certain point, the minute spherules that make up the cloud, enlarge by fusion to droplets that fall. Some of the drops that leave the cloud are larger than others, and in falling overtake the smaller ones, as the giant drops gliding down a window-pane devour the pigmies in their path.

While the answer given is incomplete, it is nevertheless useful, and should serve my purposes, for by means of it I may decide whether or not to go on a picnic, or to plant a crop. Of course I might ask for more information on evaporation, and for further details concerning the condensation of evaporated substances and whether the end-products of these two processes are identical. I might also wish to know more about the fact that sometimes a substance rises from the ground and sometimes it falls, and furthermore, how it happens that in a vacuum small drops and large fall at the same rate, but, however many

questions I might ask, from the man of science I should receive answers which, though differing in richness of detail, in principal would be invariable.

What is this principle? No matter how much the physicist, the chemist and the meteorologist might add to the chain of events as outlined, it would never be other than a chain of events. Even at the present time it might be lengthened almost indefinitely, and although this might show how much we know, it would also show no less clearly that all our knowledge is of one sort, and that scientific explanations, however many or few links we may have in our chains, never amount to more than the enumeration of the conditions under which the events in nature take place. Under the proper conditions evaporation occurs; when the conditions are right a cloud is formed; and, under the proper circumstances, rain falls. This is the chain; in it one event is the outcome of certain conditions and on its shoulders stands the next event if other conditions no less important have been satisfied.

There is something very instructive about a series of this kind, for study, not only of the conditions under which rain falls, but of the conditions under which anything whatever happens in nature, shows conclusively that all the conditions are equal in importance. We ourselves are such poor democrats, however, and so accustomed to special privileges, so much more interested in some things than in others, so inured to our worship of the exceptional and the peculiar, that when we meet with a situation like this, the language of the street, the habit of a life-time, and the teaching of centuries all unfit us for the task of interpreting nature as she really is. Nature is democratic; that which is the condition of an event is neither more nor less than that event's condition, and when, as is always the case, a group of conditions is the basis of an event, that event is suspended, or another takes its place, unless the tiniest condition has cast its vote in the primaries.

It is the neglect of this truth that leads to many of the difficulties of science, for her most ardent votaries are often bent on bestowing special favors among conditions, and now and again knight them. But knighthood among conditions is as precarious an honor in science, as a seat in the house of lords, for sooner or later the bogus knight falls in joust, and another, himself soon to be vanquished, takes his place. It has happened many times in the history of science, one need but think of the changes in the treatment of disease that first one cause, then another then a third has been assigned the leading rôle in the drama of causation, but each of these in turn has had his vizor torn off, and has stood exposed as a condition which, masquerading under the armor of special privilege, for a time succeeded in imposing on the public as a real cause. Indeed, no one who has set out on the quest for causes in science, has ever returned with anything else than a knowledge of

conditions, for the fountain of action escapes them as the fountain of youth receded before the searching eyes of Ponce de Leon. Nevertheless, the treasures on the road of the deluded are no less valuable than those strewn on the pathway of the sane, if they will but pick them up, and all the wealth of our much boasted "causal" biology has been brought home by men who were not lucky enough to get what they were after, but wise enough to take what they could find.

Those who have parted with their entire wealth of prejudice in the matter of causation can safely begin to discuss the question whether scientific explanations, explanations by means of chains of events, can be legitimately applied to vital action, and furthermore whether such explanations are useful. At the outset, however, they meet with a grave difficulty, for at the present time no one knows exactly what it is that needs to be explained. Some tell us, life is motion; others call it a chemical-physical process; whereas some declare it synonymous with consciousness. Herbert Spencer, after cudgeling his brains for many years, arrived at a statement which seemed to him, as it has to many since then, the best possible. "Life," he says, "is the continuous adjustment between internal relations and external relations."

Unfortunately none of these definitions is really satisfactory. Who, on being told that life is the continuous adjustment between internal and external relations, can feel that now he has the secret firmly in his grasp? Indeed at present a hard and fast definition is scarcely possible, and, if it were, would add more to the comfort of the dialectician than to the progress of knowledge. When we understand life the definition will come of itself, and then no one will care to use it.

Most of the biological work of to-day is an attempt to find out exactly how living things make their living, and the biologist, regardless of his party affiliations, is happy to say that all who study these questions agree that living things make use of machinery. Is not the respiratory system a machine by which oxygen is taken from the air and carbon dioxid given off to it? Is not the digestive system a factory which changes food-materials into simpler compounds that are absorbed?

The machinery of living things is very remarkable, complex, and adequate. It may not always be wholly adequate, but certainly in general it is sufficiently so. Sometimes it can be improved by surgery, by the prescription of glasses, hearing trumpets, false-teeth and tonics, but on the whole it is adequate, it is fit. Indeed, fitness more or less pronounced, but fitness, nevertheless, is the leading characteristic of living machinery and its processes, and under shifting external conditions, distinguishes them clearly from things not alive. No man need take the time to adjust himself consciously when he deals with his fellowmen, with horses, dogs and with building materials. Our famil-

iarity with the striking peculiarities of these substances is such that we pass with the greatest readiness from one to the other, and treat them all in essentially suitable ways.

What do we know about things that are fit in an ever-changing environment? In the first place they are things which have had a long history, and though we are still wofully ignorant of the conditions under which this history has been worked out, we do feel reasonably certain that all life is of a common stock, and that we have as good reasons for speaking of the brotherhood of living things as we have for speaking of the brotherhood of men. We know with much greater detail that fit things assimilate food, that they excrete wastes and that they secrete substances useful to themselves. We know too that they grow, repair wounds, and often restore very complex lost parts; that by a marvelous process of development they reproduce their kind from spores, gemmules, buds and eggs; and finally, we suspect that many of them have minds in some way like our own. We know with certainty that we ourselves have sensations, feelings, emotions, knowledge and the power to communicate much of all this to others. Strangest of all, we have a fairly complete equipment of self-knowledge, and we spend much of our time in thinking and talking about our origin and our destiny.

The anatomist tells us that things which do all this are composed of many complicated parts visible to the naked eye; the histologist analyzes these parts or tissues microscopically, and finds that they are made up of unit masses, the cells, or of the products of cells. From the embryologist we learn in detail how each of the myriad cells of the body comes from preexisting ones, and how by tracing development back to its earliest stages, we finally reach the egg. Cytology carries the dismemberment a step farther by discovering, classifying and naming, not only the minuter parts of the cell, but its very granules. Biological chemistry tells us what substances are found in the protoplasm; chemistry what elements are present and their proportion; physics that these elements are molecular in structure, that each molecule is made up of smaller units, the atoms, and finally, the newest physics of all dissects the atoms and promises to show that these, instead of being simple, are in reality constellations of electrons. When we consider that a single protein molecule may contain perhaps 2,304 atoms, more or less, that the number of protein molecules in a cell is unknown, that there are millions of cells to the man, we realize that our bodies are fearfully and wonderfully made, and that if our ears were sensitized to only a fraction of the rush and bustle within each protein molecule we should be deafened as with the roar of a Bessemer furnace.

This analysis is far from complete, but thousands of men throughout the world are contributing, each the small share which he can,

toward the unraveling of the great puzzle. Those who know most are least hopeful that we shall ever know all, but many will subscribe to the statement that the resolution into electrons is the last station suspected at the present time on the road which we are travelling. It is an interesting question, therefore, to consider what we shall have accomplished when we have resolved man by analytical methods until we can name each one of the electrons of which this remarkable being may possibly be composed.

In the distant future some Super-Zeiss may possibly make a lens more powerful and strange than Aladdin's lamp. In its focus, a man, with electrons as large as coffee-beans, would be but the transparent ghost of his real self, and the rush and swirl of his elephantine heart and the monstrous hailstorms rushing in and out of the elastic cloud-like lungs would startle and confuse even the hardened physiologist of those days. Under the circumstances the self-control constantly employed by every good observer might easily leave him and his cries of astonishment would probably be answered by cataclysmic tossings among huge masses of the illuminated brain of the man who was told to keep still and pay no attention to the professor.

The knowledge implied in all this transcends the whole of human experience, but there is no man of science worthy the name, who would not welcome it, or who does not hope that some day we shall understand these things better than now. If we throw ourselves into the future when the sort of knowledge to be got with the Super-Zeiss Illuminating Magnifier shall have become common property, we can imagine even the men on the street possessed, not only of astronomical acquaintance with living bodies, but also with the world in which these bodies live. These super-men may know that certain changes in the movement of the surrounding electrons are invariably followed by certain movements of the electrons in the brains and hearts of their fellowmen; they may know exactly what torrents and back-eddies of corpuscles occur when two friends who have not seen one another in twenty years meet on the pavement, and they may be able to describe in much detail the wild turmoil in the nervous system of the lunatic. But they will not be able to see the joy which friends experience on meeting nor the delusions of the insane. We may confidently expect them to have their own joys, sorrows, and imaginings, and that they may know what the physical concomitants of pleasure and pain in others are, but no feeling or thought will be theirs except their own. In this respect they shall be no wiser than we are, for we too can tell pleasure and pain when we meet them, but whereas we recognize them by smiles, laughter, lined faces and tears, the men of to-morrow may know these things by the movements among electrons.

Although physical analysis of men can never give us more than the

physical symbols of their consciousness, it would be the height of folly to consider this information complete, for it leaves out the most important thing about men. This greatest asset of all so transcends in value to us the knowledge of its physical basis, that even if every feeling and thought we have comes only with such changes in our brains as a skilful chemist and physicist might detect, measure and tabulate, it still remains true that we have used and are using our minds advantageously in the almost complete absence of such records. Had Shakespeare been dependent on a knowledge of the chemical changes in his nervous tissues as he wrote Hamlet, it is needless to insist that the play would not yet be written. To know a thing, to perceive and appreciate beauty, to recognize natural law and truth, all these are experiences in consciousness whose value and importance in human life no man can deny, nor can any man give a satisfactory explanation of the actions of his fellow-men without considering their feelings, emotions, and thoughts.

Since consciousness must be reckoned with in a scientific explanation of men, the question arises whether something analogous is not also true of living things in general. Does not the fitness of living things, the fact that they perform acts useful to themselves in an environment which is constantly shifting, and often very harsh; the fact that in general everything during development, during digestion, during any one of the complicated chains of processes which we find happens at the right time, in the right place, and to the proper extent, does not all this force us to believe that there is involved something more than mere chemistry and physics? Does not all this show that there must be present something, not consciousness necessarily, but yet its analogue —a vital X?

If we begin with what each one knows best of all, we may say that we can not doubt the existence of consciousness in ourselves. By intimate association with our fellow-men, and by comparing their acts with our own, we infer that they too are conscious, though we do not know this with the same certainty with which we know it of ourselves. If we descend in the scale of life, we know that it is practical to deal with many animals as though we knew for certain what in all probability is true, namely, that they also are conscious, but when we descend still farther, and reach forms built on a different plan, forms devoid of sense organs, and of brains, forms leading totally different lives, and with responses often simple and direct, what shall we say of them? Are they conscious? Is the amœba, the germinal disc of a hen's egg, or the sapling oak conscious? Nothing short of a method of communication as complete, delicate and trustworthy as the language of men, could ever enlighten us on this question, unless indeed we could transform ourselves at will into amœbæ, hen's eggs or oak trees. Even then we

might not know, for we might lose the organ of conscious memory on the way down to the beginning of things, a path up which, in a very real sense, every human being has come in person.

If the question whether living things are conscious can be answered positively in only one case, and with great probability for the rest of our fellow-men and some few of the higher animals, but not at all for the lower forms or the early stages in the development of the higher, practical needs force us to act on our ignorance, and to deal with these matters as they appear to be and not as they might be, although we cannot dogmatize and must grant the reasonableness of William Keith Brooks when he says: "As for myself, I try to treat all living things, plants as well as animals, as if they may have some small part of a sensitive life like my own, although I know nothing about the presence or absence of sense in most living things; and am no more prepared to make a negative than a positive statement." I do not know whom we should consider the greater fool, the man who went abroad declaiming about the unconsciousness of the oak, or him whom we should discover trying to teach an oak the Greek alphabet.

This is where we stand on the question of consciousness, but the question of the vital X is even more difficult, for we have no experience of it comparable to our first-hand knowledge of consciousness. I have not the faintest idea what living is like except as I know this consciously, for unconscious knowledge or experience is altogether outside my line of business. Hence if there is a vital X in ourselves other than consciousness, I know nothing about it, and if I can not even be sure of consciousness in most living things, I certainly can have no good reason for assigning to them an X of which I not only know nothing, but have no present means of knowledge.

The progress which scientific explanation has made in our own lives, however, should warn us that no one can tell what will come next. It is by no means inconceivable that some day we shall be so familiar with the physical-chemical changes which to-day we know as feelings and thoughts, that we shall be able to infer consciousness from these reactions with the same certainty with which we infer now that a match lit under the nose of a fellow-man has hurt him in much the same way as it would have hurt us.

To my way of looking at things, there are only two possibilities with respect to the vital X, and when the day comes on which the inference of consciousness from its physical symbols shall seem safe and just to the man of science, these possibilities will stand out even more sharply than they do in the present scientific dawn, for the man of the future, equipped with the knowledge with which we have endowed him, will be able to decide whether the X in question is a variety of extra-personal consciousness or a variety of nonsense.

So far as the second of these possibilities is concerned, the men of the future will be no better fitted to deal with it than we are, and as for the first it is practically like the other, and useless as an explanation for an explanation which by the nature of the case we can not understand, is a contradiction in terms.

Aside from the impotence of the vital X as an explanation, its spokesmen are guilty of reasoning unbecoming to men of science, for they attempt to furnish us with an efficient cause of vital action, a captain who steers the ship of life. But consciousness, the nearest known possible relative of the problematic X, is certainly not a cause in man's life, for however much prejudice may incline us to adhere to the opposite view, consciousness is neither more nor less than a condition. It is true that we must recognize it and deal frankly with it, for in its absence man's life assuredly would not be what it is. But the same thing might be said of respiration, of digestion, of the environment, or of any one of the multitude of conditions under which life occurs, and is what it is. And the same thing would unquestionably be true of the vital X, for if it could be proved to be something with which he who would give a scientific explanation of life must reckon, if indeed it were shown to be the element without which it is impossible to understand how the right thing happens in the right place, at the right time and to the proper degree, science instead of having engulfed a real cause, would simply be enriched by the capture of one more of the conditions under which some of the substances in nature live.

If nature were a limited system, there would be some hope of ultimate acquaintance with all the conditions of life, but as the universe is unlimited, no foundation for this hope exists, and one need but reflect, as Brooks did, on the growth of knowledge to realize the truth of these words:

> **Each scientific discovery shows us new and unsuspected wonders in nature. The unexplained things which are brought to our knowledge by each scientific explanation far outnumber the things it explains. The progress of knowledge is no mere comprehension, or gathering in. It is more like sowing seed than gathering a harvest, for the known world grows with knowing.**
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> **We are told that "when every fact, every past or present phenomenon of the universe, every phase of present and past life therein, has been examined, classified and coordinated with the rest, then the mission of science will be complete." But if we are to judge the future by the past, classification and coordination will always show us more unclassified and uncoordinated things than they classify and coordinate.**
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> **Each new encyclopedia is bigger than the one before, and so, no doubt, it will be to the end. If knowledge were nothing more than comprehension, or the analysis and classification of facts, the progress of science should be bringing us nearer to universal knowledge, but each new discovery puts it farther from our grasp than before, and they who know most, are most convinced of its**

unattainableness, not because the reality of things is unknowable, but because of the innumerable multitude of things knowable.[2]

But even if nature were a limited system and we were able to get into possession of all the conditions under which any event within this system occurs, we should still be no better off, for the external conditions under which our imaginary system would be what it is, could never be known. The student of life, of chemistry, of physics and all others, would find their experience hedged in by an impenetrable wall, beyond which they could not go. In an unlimited world, however, there can be no theoretical limit to experience, and while at any time we are actually hedged in by our ignorance, this wall is fortunately capable of being moved by human powers, and the road to further exploration is clear for all who wish to go that way.

Since exhaustive knowledge in an unlimited universe is clearly unattainable by us, it follows that a scientific explanation is a growing explanation, and of necessity always incomplete. So far as it goes, we have a scientific explanation of life to-day, but it satisfies almost no one because the most important things remain unknown, and our explanations are inadequate to meet our practical let alone theoretical needs. These inadequacies have tempted many to fill out with art what they lack in knowledge, but the deficiencies of science, coupled with the certainty that there is no limit in a limitless universe, to what we may find out, to the man who is true to the scientific standard, are the greatest stimuli, for there is no joy equal to that which comes from extending the bounds of knowledge, for even though she tells us nought of "lunar politics," nevertheless, "all the things thou canst desire are not to be compared unto her."

To many men the realization that the work of science is unending and that she can extend no hope of ultimate explanations, comes as a blow, but this is neither more nor less than the just reward of all who take the universe lightly. This particular limitation biological science shares with all her sisters, for her failure to give us anything else than the physical symbols of life is a shortcoming by no means peculiar to the application of scientific explanations to vital phenomena. The physicist might analyze hydrogen and oxygen with the same magical lens which we applied in imagination to man, and if present opinions are correct, he would see the constellation of electrons that constitute the hydrogen atom and the constellation that makes up the oxygen atom. If he were an experimental physicist, he might take an electron out of the hydrogen atom and replace it by one taken from the oxygen, and be surprised, or not, according to his preconceptions, that substitution makes no difference. Further analysis might tell him that the hydrogen

[2] Brooks, W. K., "Intellectual Conditions for the Science of Embryology," *Science*, Vol. XV., pp. 453–454.

constellation differs in the number and movement of its constituent electrons from the oxygen constellation, and that both constellations are differently related to the rest of the world, but why one set of relationships should be hydrogen and the other oxygen would be revealed to him as little as it will ever be revealed to the biologist why one kind of corpuscular movement in the brain means pleasure, whereas another means pain.

Unfortunately, the biologist has no more senses than any other man; all that he tries to do is to use those he has to the best of his ability. It so happens that the senses with which he learns, and the brain with which he reflects, have evolved from simpler conditions, but however different the early stages of these organs may have been, they were elements in the fitness of his progenitors, and he believes that his natural endowments, limited though they be, are no less serviceable to himself and his fellows now than they were in pre-historic days. To-day more than at any previous time in the history of civilization it is coming to be recognized that the results of the application of our senses to the study of nature are racially essential. Another and closely related truth, however, still has to fight hard for its daily bread, for it is unfortunately by no means generally known that scientific results are not, and can not be, got directly for the asking. Most men of his day, had they known about it, would have considered James Watt a fool, for instead of watching the steaming mouth of a tea-kettle, a thing which millions of men had seen before, and have seen since, and to no particular advantage either, he might have been occupied with the more obviously useful task of chopping wood for the fire; yet to these fireside dreams we can trace the whole of modern travel by steam. Perhaps Gregor Mendel, in the opinion of those who saw him pottering over his peas, would have done better to devote more time still to the affairs of his extraordinarily well-run abbey, yet upon his careful, thoughtful and beautiful observations rests the modern science of heredity, and the hope for the betterment, not only of our plants and animals, but of our very selves. Perhaps the man who hunts for frog spawn in the early spring would be better occupied removing the ashes from his cellar, yet it was a man with just this vagary whose tadpoles not only enlightened him and all the world as to the manner in which nerve fibers grow, but the methods developed in the course of these studies are now being applied for the purpose of determining the conditions under which cancerous growths occur, and consequently are freighted with the possibility of both the prevention and cure of this terrible scourge of middle and old age.

This is the method by which scientific explanations and their application come about, and however much we may regret that knowledge does not grow more simply and directly, the reason for this lies in the

structure of nature herself. Nature is a great system of things wherein mediately or immediately everything is related to everything else, and the scientific problem is the discovery of these relations. That many of them are so remote that no man could have foreseen them, is not our fault.

It is this remoteness of natural relations that so frequently startles us when discovered, and it is likewise the remoteness of things that justifies every stroke of work on problems the solution of which no man can evaluate in gold or silver. Indeed our usual standards break down completely here, for the measure of science is not in money, but in happiness, and the market value of this is uncertain, since no man, consciously or at least voluntarily, places his own happiness on sale. To ask for the monetary equivalent of the scientific discovery that our bodies are derived from a single cell, is like asking for the price of a friend. Brooks, in a suggestive paper on universities, wrote:

> While the benefits which learning confers are its only claims to consideration, these benefits will cease as soon as they are made an end or aim. All men prize the fruit, but . . . the tree will soon be barren if they visit it only at the harvest; they must dig about it and nourish it, and cherish the flowers, and green leaves. The gifts of learning are like health which comes to him who does not seek it, but flies farther and farther from him who would lure it back by physic or indulgence.

If material benefits, however, had been the only products of scientific explanation in his day, Huxley, according to his own confession, would not have been cared greatly to toil in the service of science, but would have enjoyed equally well the less complicated activities connected with quietly chipping his flint ax after the manner of forebears a few thousand years back. He tells us:

> The growth of scientific explanation has not only conferred practical benefits on men, but in so doing has effected a revolution in their conception of the universe and of themselves, and has profoundly altered their modes of thinking and their views of right and wrong. I say that natural knowledge, seeking to satisfy natural wants has found the ideas which can alone still spiritual cravings. I say that natural knowledge in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundations of a new morality.

It is more important, infinitely more important, that I should know and understand the immediate as well as the remote consequences of any action of mine, than it is that I should travel in seventeen hours, in luxury, to New York, and scientific explanation enables me to do both.

It is because we are apt to be so much more impressed by a practical application than by the conditions under which such application is possible, so much more by prominence than by importance, so much more by the gun than by the man behind it, and lastly because science modestly acknowledges her limitations, that she has fallen into ill

repute in many quarters. But Cinderella, to paraphrase Huxley's apt characterization of science, modestly conscious of her ignorance in high matters, lights the fire, sweeps the house and provides the dinner, and in reward for this, is called a base creature, devoted to low and material interests. But this charge shows nothing so well as ignorance of her ways, for in her garret she has visions of the order which pervades the seeming disorder of the world, visions of the great drama of life, with its full share of pity, terror and also of abundant goodness and beauty. She has at her command, knowledge which she is ever ready to place at the service of those who will use it, and she knows enough about ethics to foretell social disorganization from immorality with the same assurance with which she predicts bodily diseases from physical trespasses. No brighter light than hers is set for mortals in all the firmament, and by its light, dim though it be at times, we must walk, devoutly thankful for the few rays of insight that now and again illumine the path.

SOME FEATURES OF THE ROOT-SYSTEMS OF THE DESERT PLANTS

By Dr. W. A. CANNON

DESERT LABORATORY

THE roots of the desert plants are of interest, in part because of their relation to the physiological activities of the shoot, and in part because of their own physiology. There is a close relation between the character of the roots of the desert plants and the distribution of the plants, and probably with many other activities of the plants, as, for example, the formation of the leaves, of the flowers and the taking on of new growth. What the precise relation may be between the root-systems and the adaptation of desert plants to desert surroundings is not known, nor, for that matter, the relation of the roots of the plants of the more humid regions to their distribution, or to their origin. Also the special relation of the roots of plants to the substratum has not been extensively investigated, as, for example, the character of root development as related to the precise per cent. of water content, or to the temperature. The lack of quantitative experimental studies on roots in soil is to be attributed in large part to the difficulty in studying the soils. If certain activities of the roots, or the significance of root character to many features of the plants' activities, are to be understood, it will be necessary to do quantitative experimental work on plants *growing in the soil,* and not, as heretofore extensively done, growing under highly artificial conditions.

It is popularly supposed that the roots of the desert plants are very long—that is, that they penetrate the ground to great depths, and from this that the length of a root-system is in some way a measure of the aridity of a locality. It is difficult to say how this idea arose, which really is without adequate foundation, because a relatively small amount of work has been done on the roots of the plants either of the humid regions or of the deserts, in the field. It is probable, however, that the few excavations that have been made have been carried on in those places where it chanced that the roots penetrated to great depth. But it is in exactly these places where the most favorable moisture conditions of the given locality are to be found, namely, where the soil is deep, giving an opportunity for the penetration of water to a great depth, as in the bottoms, or along the banks of stream ways—arroyas in our southwest, ouedes in southern Algeria, or weds in the eastern Sahara.

From this it is to be seen that the localities referred to, instead of being typically intense deserts, are, on the other hand, the most favorable situations as regards moisture.

It is difficult, at present, to state under what conditions the roots of the desert plants are formed, owing mainly to the lack of experimental evidence. But by a system of reasoning backwards from the mature root we can possibly picture to ourselves something of these conditions. In the first place, if we examine the root-systems of desert plants, in the field, during the season of drought, we shall find it very difficult, if not impossible, to find any portions which show vegetative activity, although it may be possible at the same time to demonstrate a certain, even if low, rate of transpiration. On the other hand, if the root-systems of the desert plants are examined during the rainy periods, there will be no difficulty whatever in finding fresh growth, new rootlets of whatever kind. But that this is not the whole story is evidenced by the fact that in winter many of the plants native to the southwest do not form new roots, or, at least, I have not been able to find new roots. In spite of this fact, such plants as the flat opuntias do, in winter, absorb water and very promptly after rains. This is shown by the thickening of the fleshy and flat stems. It is therefore probable that a certain amount of heat as well as of moisture is required to bring about the formation of fresh roots. In addition to these two factors, there is probably another one, namely, aeration of the soil. Whether this is mainly concerned with the formation of the roots or of the position occupied by the roots in the soil is not known. It seems highly probable in certain cases, particularly in fleshy plants like the cacti and some liliaceous forms, that the amount of air in the soil must be of importance in determining the position occupied by the roots. So far as observation goes, the roots formed may be classed in at least two categories: (1) They constitute the extension of the roots previously formed and (2) they may appear on much older roots, but are of limited growth. It is supposed that in the main the greatest amount of water taken into the plant comes through the roots of the first kind, so that the place of water absorption as the roots grow, ever becomes farther from the stem, and the problem of water transportation is ever an increasingly difficult one. This last one is probably to be considered a very important matter on the desert where the evaporation rate is often very high, caused by the low relative humidity, by high temperature and by air currents. It is conceivable that, given favorable conditions, a large proportion, possibly all, of the roots of this character might remain alive, but, as a matter of fact, in desert plants, as before noted, it is difficult during the dry seasons to find any living roots of this class. As one result of this we find that the extension of the root-systems as a whole, away from the central plant axis, goes on relatively slowly, and

probably most of the rootlets formed in any season perish before the close of the succeeding dry season.

As regards the second class of roots referred to, there is quite a different story to tell. These roots are apparently quite as deciduous as the leaves of many plants. It should be noted, however, that nothing has been done in an experimental way to test the longevity of these roots, and it is reasonable to suppose that under some favoring conditions they might endure, possibly becoming converted into large laterals, even if under conditions, which are the usual ones, their life is limited.

It may be well to describe the roots referred to. If we examine a root of such a desert shrub as *Franseria,* we shall find, along such of the roots as extend in a more or less horizontal direction from the stem of the plant, groups of filamentous rootlets. These occur at about 1 cm. intervals, in varying numbers usually about one half dozen together. They are from two to four cm. long and probably not more than one half millimeter in thickness. The rootlets appear promptly with the coming of the summer rains, and they cease their activity when the soil attains to an unbearably dry condition, as perhaps in adobe soil, 10 per cent. moisture, more or less.

The deciduous rootlets greatly increase the absorption surface without, at the same time, necessitating invasion of new root areas, or of causing a long transfer of water from the place of absorption to the stem. So far as is known, the deciduous rootlets are formed only when there is an abundance of water, and when the temperature is high. These rootlets have been seen on most of the desert shrubs, on all in the vicinity of the Desert Laboratory, and have been observed on a few of the shrubs in southern Algeria. Whether a similar kind of rootlets occurs on perennials in the more humid regions is not known to me.

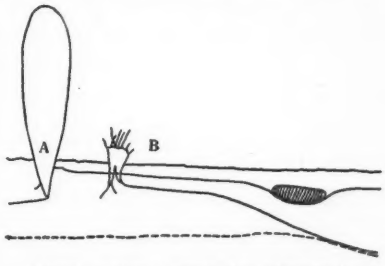
The deciduous rootlets are thus of great importance to such desert plants as bear them. They appear adventitiously always, and apparently in the same place on the root year after year. In certain species it has been observed that the adventitious roots are formed precociously, but in other forms this is not the case. And again, where such rootlets are not to be found, it appears that they can not be induced.

The extension of the roots of the desert shrubs is various, perhaps in no case exceeding three or four meters. The position in the ground is also not uniform. In most instances the position occupied by the roots is characteristic for the species, but it is likely that the extension of the root-systems varies mainly with the age of the individual.

There are three main types of root-systems to be found in the shrubs of the desert plants of the southwest. (1) Root-systems which extend horizontally from the main plant axis and lie, for their whole course, near the surface of the ground. (2) Root-systems which are characterized by a strongly developed tap root going directly down to a depth

determined in part by the character of the soil, in part by the penetration of the rains and in part by the character of the root itself. (3) And roots that not only reach widely, but also penetrate fairly deeply.

The superficial root-system (Type 1) is characteristic of many plants, particularly of the cacti. In some instances all of the roots except the anchoring roots, which, however, may not penetrate more than 50 cm., may not be more deeply placed than from 2 cm. to 5 cm. so that with a cane one can easily remove the root and then with little exertion can strip it from the soil to the base of the stem. Perhaps the root-system of *Opuntia arbuscula* (?) is the most superficial of any thus far described. In this species the ideal superficial root-system just alluded to finds complete expression. But the giant cactus also, although it is now reckoned among the trees, has a root-system which is essentially superficial. The accompanying figure gives a good idea of the position occupied in the ground by the root-system of a small giant cactus. The plant referred to was 1.2 meters high. The supporting system consisted of a stout root crown from which proceeded a few relatively slender branches, and the main absorption system consisted of long, slender branches and superficial roots which extended as far as three meters from the base of the plant. It may be said, in passing, however, that as the giant cactus becomes large, the anchoring system, sufficient in its younger stages, is no longer strong enough, and the bases of the superficial laterals increase greatly in thickness and form props by which the upright position of the cactus is maintained.



Giant cactus (*Carnegiea gigantea*), *A*, VERTICAL EXTENSION OF GIANT CACTUS. growing in association with a creosote bush (*Covillea tridentata*), *B*. The anchoring roots of the cactus and the superficially placed absorbing roots are shown in position. It will be seen that the roots of the creosote bush, which are of the generalized type, occupy a lower position in the soil than those of the cactus. Between the surface of the soil and the dotted horizontal line is the adobe soil, here about 30 cm. in thickness. Below the dotted line is the hardpan, caliche, which is impervious to water and is not penetrated by the roots.

There are several plants which illustrate the pronounced forms of the tap root, among which, in southwestern Algeria, may be cited the *Tamarix,* and certain other small shrubs, and in our own southwest such a form as palo christi, or Christ's thorn. *Zizyphus* also, which occurs both in southern Algeria and in the southwestern part of the United States, has a pronounced tap root. I will refer especially to the root-system of palo christi (*Koerberlinia spinosa*). The *Koerberlinia spinosa* is a close-growing, spinous shrub without leaves at any stage,

which grows in the bottoms, or along the sides of the bottoms, in the vicinity of Tucson. The young plants have roots which strike directly downward, giving off almost no laterals within one meter of the surface of the ground. The depth to which the tap root attains has not been determined. As the plant becomes older a sucker is sent out close to the surface, from which there springs up a daughter plant. Adventitious roots occur along the course of this sucker, particularly where the daughter shoot arises. Occasionally the connection between the daughter shoot and the mother plant is not destroyed, and the adventitious roots in that case are not very numerous nor very long. Sometimes, however, the connection between the plant and offspring is broken and the adventitious roots, or one of the adventitious roots, strike straight down and behave precisely as the main root of the parent plant. That is, in this case, as in the *Zizyphus* and *Tamarix,* the root-system is an *obligate* deeply penetrating one, for which reason the species is confined to such localities as provide sufficient depth of earth.

The third type of root-system, which may be called a generalized type, is such as is possessed by most of the plants growing in the vicinity of the Desert Laboratory, and in fact by most of the desert plants. Perhaps it would be clearer to state this in another way, namely, that the plants which cover the greatest area in the arid region are such as have the generalized type of root-system. It will only be necessary to refer to the root-system of the creosote bush of the southwest for an example of this type. The roots of the creosote bush extend outward from the main stem for a distance of about three meters, less in small plants, and reach downward, either directly or at an angle, to a depth which is usually determined by the character of the soil. On the mesa, where the soil is usually less than one half meter in depth, the roots of the creosote bush do not exceed that depth, but in the beds of the washes, or rather on the flood-plains of the washes, where the soil is deeper, they have been known to attain a depth of over two meters. From this it is seen that the generalized type of root-system is more flexible than either of the other two types given, and it follows, other conditions being equal, that species with the generalized type of roots may also have a wider local distribution.

It is interesting to note that the most arid portions of an arid country are the areas which are above the flood places of the washes. In the southwest these are usually the mesas. In southern Algeria, for instance, these excessively dry areas are the regs, or the hamadas. It is to lower-lying areas, washes and the flood-plains of the washes that drainage from the higher ground flows, and also where particles of soil from the higher ground are deposited through water or through wind action. And the result is that the low-lying areas have deeper soils and more water than the upland.

We therefore conclude from what has just been said that the most arid portions of such deserts as those in the southwest of the United States are on the higher lands, and the less arid portions in the lower lands—the flood-plains or the washes—and that it is only in the less arid areas that plants with pronounced tap roots occur.

It should be definitely pointed out that the foregoing classification of roots is applicable only to such deserts as that of the Tucson region, where a portion of the flora consists of plants with a water balance. In the more arid regions, such, for example, as southern Algeria, fleshy plants are almost entirely absent, and root-systems characteristic of such plants are consequently not to be found. We therefore have in the most intensely arid desert plants with two general types of root-systems only, namely, the generalized type and that form which has a well-developed tap root. In southern Algeria, for example, species of the genus *Haloxylon* have a modified generalized type of root-system, and this species occupies the plains—the reg or hamada—where the soil is least abundant and hence where the water relations are least favorable. In the hollows of the plains where soil has accumulated to some extent, and along the washes or oueds, we find plants with the main root especially well developed. In fact, it is only where the soil is actually or relatively deep that such forms as *Tamarix, Zizyphus* or other relatively large forms all having long deep roots, are to be found. From the character of the roots of plants from the plains of southern Algeria, as well as the roots of plants from southwestern United States it is to be seen, therefore, that if any type of root is entitled to be called the xerophytic type, it is the generalized form, and not the deeply penetrating tap-root form which is thus seen to be the peculiarity of plants which grow where conditions are relatively favorable.

Turning now to consider briefly the environment of the roots of desert plants, we should note, in the first place, that the root environment of these plants is not at all well understood. This, of course, comes partly from the fact, as before pointed out, that the soil is difficult to study. However, certain features of the soil, such as the water content, the temperature, and certain other features, which are best known, can be treated briefly.

As a general thing the rains of the desert do not penetrate the soil to any considerable depth. In the Tucson region, where the rainfall does not exceed 30 cm., the penetration of the ground is usually not over 50 cm., although this varies with the variation in the character of the soil. The water table usually lies so deep that the water is not available to the plants. On the mesa, in the vicinity of Tucson, for example, the water table is frequently 25 meters, or more, deep, but on the flood-plain of the Santa Cruz River, it varies from 3 to 10 meters. Under earlier conditions, which need not be described in this

place, it is probable that the water table on the flood-plain of the Santa Cruz River, nearer the surface than at present, was tapped by the roots of the larger plants, for instance, the mesquite, growing there. The depth to water in other desert regions, as for instance, southern Algeria, is very variable, but usually great. For example, at the daya of Tilrempt, on the northern edge of the Sahara, the water lies between 50 and 90 meters deep, while in the vicinity of Ouargla it is frequently no deeper than 1.5 to 2 meters. In the latter case, however, the water is highly charged with salts.

The length of time that the water in available amounts remains in the soils following storms is a variable one. In the vicinity of Tucson the soils of the river flood-plain, and of Tumamoc Hill, remain moist for a period exceeding six weeks, but the deeper levels are moist for a somewhat longer period. It has been stated that in the vicinity of Tucson, at a depth of about 20 cm., the soil is sufficiently moist to be of benefit to plants throughout the year. However, it should be said that if the activities of the perennials, or of the annuals, can be taken as indicators, the period of maximum activity, which should indicate the optimum water content of the soil, is not of long duration, perhaps not exceeding six weeks, which would include the rainy season.

A relatively small amount of work has been done on the temperature of desert soils. For a period of about five years there has been kept at the Desert Laboratory a continuous temperature record at two depths —15 cm. and 30 cm. But only a relatively few observations have been made at a depth of 2.5 cm. As a general result of the soil temperature studies it can be said that at the depth of 15 cm. the greatest diurnal range, which usually occurs in March and July, is 12° F. The extreme yearly range at this depth is 73° F. In January the temperature begins to rise, and rises gradually until the last of March, when the rate becomes accelerated, so that by the last of spring the soil approaches the temperature characteristic of summer. The highest temperatures occur in July just before the midsummer rains. When the rains come the temperature falls 5° or 10°. The minimum for the year is reached in December.

Soil temperatures at the 30 cm. level are very different from those just given above. In the first place, the daily range in temperature is usually not over 2°, and the maximum not above 4°. The minimum temperature at a depth of 30 cm. occurs in March. In the first part of April the soil begins to get warm and the temperature arises until the rains of midsummer. The fall in temperature of the soil occurs during seven months of the year and the rise in temperature of the soil at this depth occurs during five months of the year.

Unfortunately the temperatures for 2.5 cm. depth have not been taken throughout the year, but are available for spring months only.

So far, however, it would seem that the variations in the temperature of the soil at that depth are considerable. For example, one day in the spring the variation at the depth of 30 cm. was 3° F. At the depth of 15 cm. it was 11° F., while at the depth of 2.5 cm. it was 40° F. The greatest difference in maximum temperature at any moment was on April 15, when there was a difference of 23.5° F. between the upper two levels.

From what has been said regarding the soil temperatures it will appear at once that at any moment during the daytime the roots of the desert plants are subject to a very large temperature stress. Those roots which penetrate most deeply, where probably moisture is the greatest, are in the coldest soil, while such roots as lie near the surface of the soil, where the moisture conditions are least favorable, are in the warmest soil. We therefore have the interesting paradox that roots placed where there is the most water are not so advantageously placed, physiologically speaking, as those roots where there is least water, for the reason that low temperature retards absorption. This is probably of considerable importance to perennials whose root-systems live throughout the year, but its exact effect has not been studied.

While speaking of the temperature of the soil, it may be interesting to glance briefly at the effect on the development of the root-systems of desert annuals which is brought about by a variation in the relation of the temperatures of the soil and of the air. Briefly stated, the case is as follows: In the "Root Habits of Desert Plants"[1] the root-systems of the winter annuals are described as being easily distinguished from the root-systems of the summer annuals, because among other features the former have a more prominently developed tap root, and a poor development of laterals which are generally filamentous, or at least extremely slender. The summer annuals, on the other hand, have root-systems which resemble the generalized type, above described, of certain perennials; that is, the laterals are developed well, they are frequently rather coarse and the main root is often forked, thus the absorbing surface of the summer annuals is apparently greater than those of winter. The apparent reason for this difference is as follows: When the rains of summer come, the air temperatures fall disproportionately to the decrease in temperature of the soil, so that the soils are moist and relatively warm while the air is moist and relatively cool. In winter, on the other hand, the soils are always cooler than the air, which sometimes may be very warm. Under the first conditions the root absorption is favored, but under the latter conditions root absorption is not favored—conditions which lead to a strikingly different development in the two types of plants.

[1] W. A. Cannon, Publication No. 131, Carnegie Institution of Washington, 1911.

We can only consider briefly the root-air relation, since little work has been done on the soil atmosphere. We therefore do not know the rate of movement of air in the soil, or, for that matter, its composition. It is probable that there is a large per cent. of carbon dioxide where there are a relatively large number of roots of plants, but as to the diffusion of oxygen from the air into the soil or the diffusion of carbon dioxide from the soil into the air, little appears to be known. Preliminary tests show that there may be more movement of the air in the soil than might at first be supposed, and that varying, even if small, atmospheric pressure may directly affect air movements in the soil. For examples, if a tube 50 cm. long and 2 cm. in diameter be filled with soil composed of sifted sand and adobe—one part of the former to two parts of the latter—it will be found that a water pressure of only 1 cm., or less, will be required to force a continuous stream of air through it. The pressure given is for soil saturated with water. When air-dry, there is almost no resistance. In soils of this composition, therefore, it is probable that ordinary variation in atmospheric pressure is sufficent to induce in it rapid air movements. Preliminary experiments, in which a stream consisting of 20 c.c. of air a minute was passed through the soil where the roots were placed, indicated by the great vigor of the plant, and the relatively extensive root development, that that amount of air was beneficial to development and forwarded growth. Variations in temperature with depth of soil, variations in water content of the soil, are both additional potent factors in modifying the rate of movement of the soil air.

While it is not known in an exact way how the atmosphere of the soil effects the position or certain other features of the root-systems of plants, it seems probable that in certain cases, at least, the effect is pronounced. For example, as has been shown above, the root-systems of the cacti without exception are placed near the surface of the ground. The roots grow in a soil horizon which is not the most moist, but, on the other hand, which although moistened first is also the first to give up its water, and it very likely is the optimum air content of the soil at a critical period which determines the superficial placing of the roots. It is a well-known fact that many bulbous plants require well-drained soil, which is probably only another way of saying that they thrive best in soils having good aeration. Two or three experiments may be cited which may be taken to substantiate the conclusions just stated. For example, there grows in the vicinity of Tucson a cylindro-opuntia (*Opuntia arbuscula?*) in which the root-system is fleshy, the roots having much the appearance of slender sweet potatoes. It was supposed at first that the fleshy roots of these species was a specific character, which, indeed, may be true, and therefore *obligate*. Some doubts, however, have been thrown on this conclusion from observations on another

species of opuntia (*Opuntia vivipera*) in which the roots of one and the same individual may be either fibrous or fleshy. Also species resembling *Opuntia arbuscula,* but possibly another species, which grows in the vicinity of Sacaton, Arizona, appears to have fibrous roots only. It has been found also that the seedlings of many cylindro-opuntias have fleshy roots. This last may be taken to be a temporary or juvenile stage, but probably is not, for reasons which will appear directly. With the above and other observations in mind, specimens of opuntias of several different species have been grown in saturated soils, with the uniform result that the roots formed in the saturated soil were fleshy. This result might be taken to indicate the immediate effect of an abundant water supply, but in the end it may be found that the result, in part at least, may be attributed to the air relation.

There is another relation which has not been referred to and which is of great importance, namely, the osmotic relation. This can be given briefly. A strong impetus to the study of this relation has recently been given by Fitting,[2] who has shown that the shoots of certain desert plants may possess a very dense cell sap, so concentrated in fact that an osmotic pressure as great as 100 atmospheres has been determined, which pressure may even be exceeded. In the cells of the shoots of ordinary mesophytes the usual pressure is said to be from 5 to 11 atmospheres. While it has not been shown that the cell sap of the root hairs of such desert plants as have high osmotic pressures in the cells of the shoots is isosmotic with them, yet it has been assumed that the roots of these plants contain a very dense sap, as is probably the case. There is an apparently direct relation between the dryness of the habitat and the concentration of the plant juices, by reason of which the desert plant can absorb water from an intensely dry soil. As a rule the highest osmotic pressures, therefore, are to be found among perennials living in the driest situations, and during the most arid seasons. From this condition it is of interest to note that it is probably those plants in which the generalized type of root-system is to be found, or a type approaching this, that possess the most highly concentrated cell sap, since it is plants having this form of roots, as was noted above, which occupy the most arid habitats. We may conclude from this additional evidence that, so far as the Tucson desert is concerned, it is not the most deeply penetrating type of roots which are to be considered the desert form *par excellence,* but, quite the contrary, it is such a root as can both reach out widely and penetrate as deeply as the soil permits and in which there is developed a cell sap of extremely high concentration.

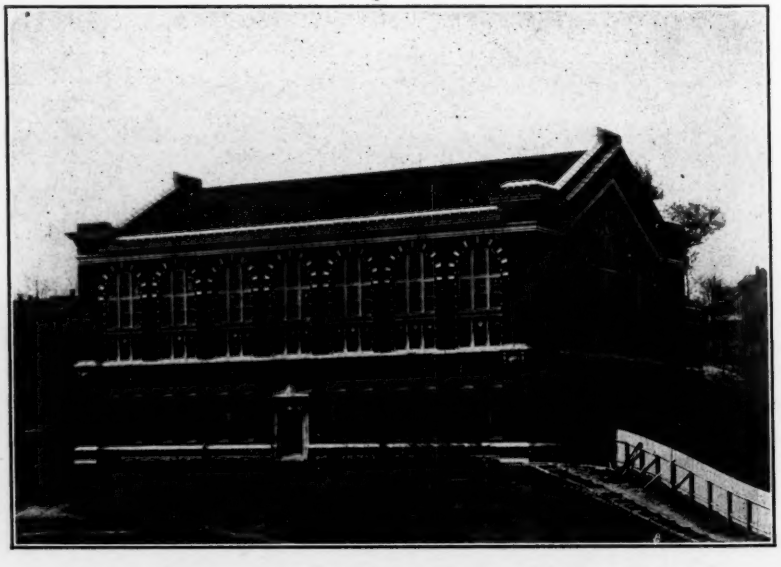
[2] "Die Wasserversorgung und die osmotischen Druckverhältniss der Wüstenpflanzen," *Zeitsch. f. Bot.,* 4, 1911.

THE PROGRESS OF SCIENCE

THE UNIVERSITY OF CINCINNATI AND ITS COOPERATIVE ENGINEERING COURSE

At its recent commencement exercises, the University of Cincinnati celebrated the opening of its new engineering building and the graduation of the first classes from the cooperative engineering course. The university itself and its cooperative engineering course are among the most interesting and promising educational experiments now in progress in this country. Cincinnati is the only city which maintains a municipal university. The state universities are the best witnesses that can be called in favor of our democracy. An institution such as the University of Wisconsin, liberally supported by the state and repaying many fold this support, covering the whole field of university work from the most special research to the most practical extension of knowledge among the people, has demonstrated what a democracy can do for a university and what a university can do for the state which maintains it.

But centralization and great size have their dangers. It seems to be neither desirable nor possible for the university of a state to provide education for all its citizens. There are at present about twenty thousand students in the universities and colleges of the state of Ohio. The number has doubled in the past ten years and will probably again double in the course of a decade; within thirty years it may be expected to be between one and two hundred thousand. Under these circumstances it seems to be necessary that not only the state but also the larger cities should maintain universities. The University of Cincinnati has demonstrated that this is feasible. At the beginning there may be neglect or political intrigue, but these are sure to be automatically outgrown as in the case of



The Gymnasium of the University of Cincinnati.

THE ENGINEERING BUILDING OF THE UNIVERSITY OF CINCINNATI.

the state universities. In the end the university is likely to become a center of civic pride, providing higher education locally and coordinating the libraries, museums and other institutions of the city.

The University of Cincinnati in June dedicated not only its fine engineering building, but also a gymnasium, the two buildings having been erected by the city at a cost of $550,000. At the same time President Dabney was able to announce that gifts from private citizens were the largest in number and the greatest in amount—about $250,000—ever received. There is no reason why private citizens and alumni should not give as liberally to a municipal or state university as to a private corporation, and we may expect to see a still more remarkable growth of state-supported institutions as the alumni increase in numbers, in wealth and in power.

One of the advantages of having local universities rather than only a central state institution is illustrated by the cooperative engineering course of the University of Cincinnati, from which students were this year for the first time graduated, and it is an interesting fact that the first experiment of this character should have been initiated by the first municipal university. Owing to the initiative and skill of the dean of the college, Professor Herman Schneider, arrangements have been made by which students work alternate weeks at the university and at commercial shops. The theory is taught at the university and the practise is obtained in the manufacturing plants. Students are paid for their work in the shops at the same rate as other men doing the same work, and no inconvenience is caused by the plan of alternate weeks as the men work continually in the shops in two relays. Students can thus practically support themselves while they are taking the engineering courses in the university. They probably learn more in the shops than by practical courses which the universities could arrange, and the shops obtain superior

men. The course is five years, and students probably can gain as valuable an education during this time as in four years wholly devoted to engineering studies. Night schools, extension courses, correspondence schools and the like are all useful, but the plan of working half the time at the university and half the time in practise seems to be superior to any other. There is no reason why the system should not be extended in other directions, as to teachers in the public schools of a city. The University of Cincinnati is certainly to be congratulated on having inaugurated a movement which demonstrates the peculiar usefulness of a municipal university.

THE ACTIVITIES OF THE CARNEGIE FOUNDATION FOR THE ADVANCEMENT OF TEACHING

THE Carnegie Foundation has published a bulletin on medical education in Europe, prepared by Mr. Abraham Flexner, with an introduction by Dr. Henry S. Pritchett, president of the foundation, which, like its predecessor on medical education in the United States and Canada, issued two years ago, is a document of considerable interest. It appears that in the German Empire, in Austria and in France there is about one physician to each two thousand of the population, in Great Britain about one to 1,100, while in this country there is one physician for 568 persons. The distribution is naturally such that the supply of physicians is relatively much greater in the cities than in the country districts. This is a difficulty which, as Dr. Pritchett indicates, can probably be overcome only by some sort of state support. It is emphasized by the fact that the abler physicians are likely to be drawn to the cities, while it is in the country, where hospital facilities and specialists are lacking, that physicians are needed who are able to meet every emergency.

Mr. Flexner and Dr. Pritchett hold that the supply of physicians in this country is excessive and demoralizing, and place the blame on the large number and low standards of our medical schools. It is not, however, certain that in view of our greater wealth the supply is relatively larger than in Europe; nor is it certain that conditions would be greatly improved by suppressing the weaker schools. If it were possible to select in the right numbers the men best fitted to become physicians and to give them the best possible education, this would clearly be the most desirable state of affairs; but such ideal conditions do not obtain anywhere in our complicated civilization. Medical education is already so prolonged and expensive that if requirements are further increased the career will be open only to the rich; it seems necessary to train more physicians than are needed in order that the best may be selected, and it does not follow that those who are unable to support themselves as physicians are the worse for having had a medical education. It would be well if more children were born to fit parents and fewer to those who are unfit, and the apostles of eugenics are performing a useful service in preaching from this text. But the Carnegie Foundation places itself in the position of the practical eugenicist who would put unfit parents out of the way. This is a delicate and difficult undertaking, which one is scarcely prepared to entrust to Dr. Pritchett and Mr. Flexner.

The proprietary schools without proper laboratory and clinical facilities are probably being eliminated about as rapidly as is desirable. The American Medical Association publishes annually a list of those which are inadequate, and the Carnegie Foundation has given wide publicity to the deficiencies of these institutions. Such information is desirable, but it may be that the Carnegie Foundation is not the best agency to exploit it. Thus the foundation refused to give pensions to the professors of the University of Illinois at Urbana on the ground that its medical school in

THOMAS HARRISON MONTGOMERY,
Late professor of zoology in the University of Pennsylvania.

Chicago did not maintain standards sufficiently high, and the university has just now abandoned its medical school. This may have been the best thing to do, but it seems undesirable that a private foundation should be able to dictate by purchase the educational policy of a state university.

The conditions are of such great educational and public concern that they should be clearly understood. The powers of the Carnegie Foundation may be illustrated by an example. It was originally established to grant pensions for length of service as well as for old age and disability. The length of service pensions were abandoned through lack of means, but the trustees, practically all of whom are university or college presidents, instructed the executive committee to "safeguard the interests" "of those whose twenty-five years of service includes service as a college president." Under this clause Dr. Wilson, when retiring from the presidency of Princeton University to be a candidate for governor of New Jersey, applied for the pension to which he was entitled by his services. The application was refused, and in some way information in regard to the matter was made public to Governor Wilson's political injury. The trustees at their last meeting rescinded the resolution in favor of the university president, and Dr. Pritchett states in his report that "no person has ever been retired under this authority." But the president of the State University of Iowa, not in an accepted institution and not eligible to retire for age, was granted a pension in August, 1911. The members of the executive committee of the foundation are in politics strongly opposed to Governor Wilson, and the secretary of the foundation was elected to the vacancy caused by the retirement of the president of the University of Iowa. Their action may have been altogether uninfluenced by these considerations; but they illustrate the dangers possible under a centralized pension system in which the pensions may be used by the president and the executive committee for ulterior purposes.

SCIENTIFIC ITEMS

WE record with regret the death of Wilbur Wright, eminent for his achievement in the development of the aeroplane; of Dr. William McMichael Woodworth, of the Harvard Museum of Comparative Zoology, and of Dr. Ed. Strasburger, professor of botany at Bonn.

THE Carnegie Institution of Washington has undertaken to publish the manuscripts left by the late Professor C. O. Whitman, including their preparation for the press and the maintenance and further study of the collection of pigeons that he left. Dr. Oscar Riddle is in charge of the work.—As a memorial of Professor Ralph S. Tarr a volume is to be published consisting of essays on physiographic and geographic subjects by men trained under him.—At a meeting of the London Institution of Electrical Engineers on May 16, a marble bust of the late Lord Kelvin was presented to the institution on behalf of Lady Kelvin.

PROFESSOR THEODORE W. RICHARDS, of Harvard University, has been awarded the Willard Gibbs medal by the Chicago Section of the American Chemical Society.—Dr. Franz Boas, professor of anthropology at Columbia University, has been given the doctorate of science by Oxford University.